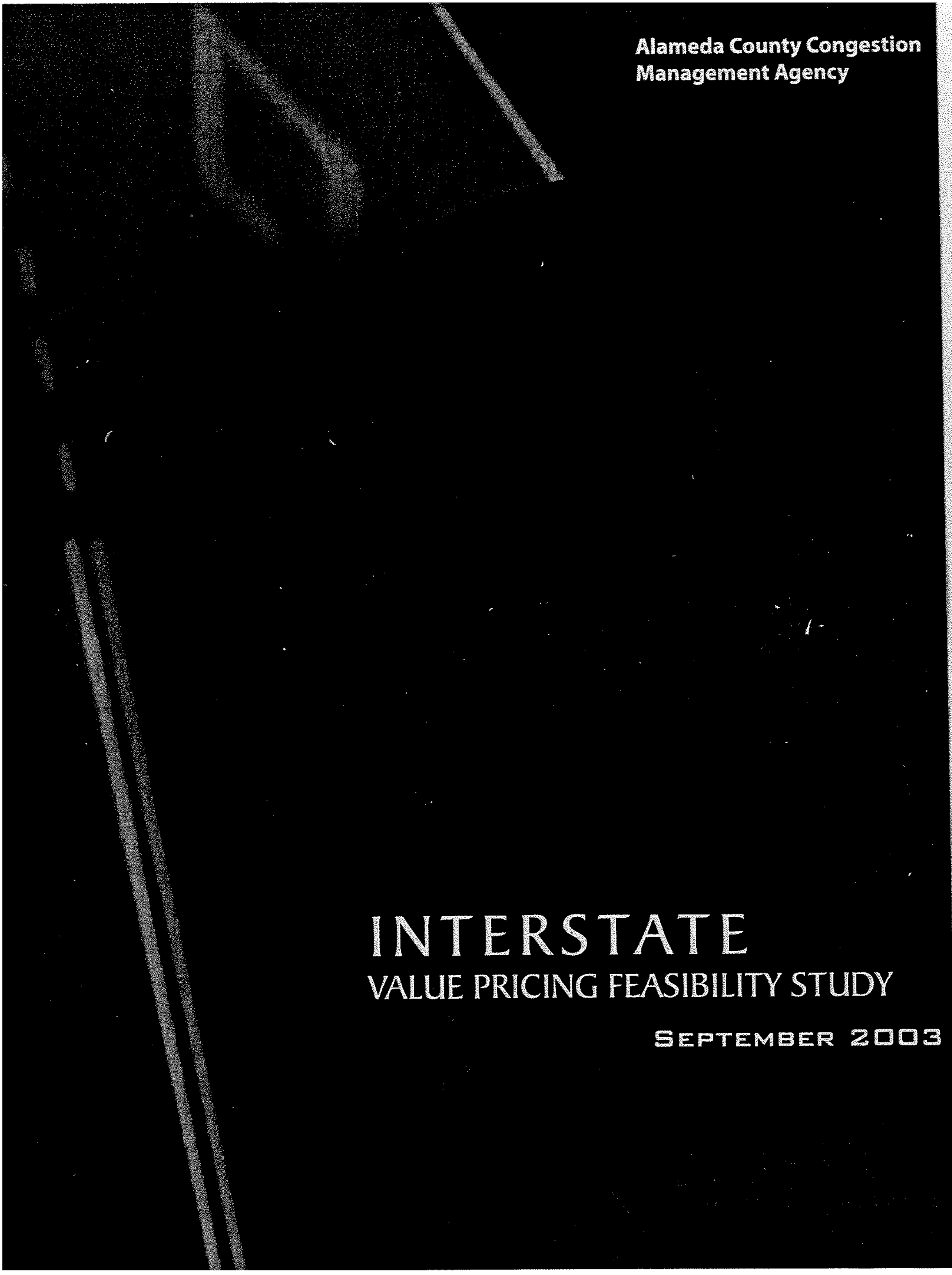

Alameda County Congestion Management Agency

INTERSTATE
VALUE PRICING FEASIBILITY STUDY

SEPTEMBER 2003

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INTERSTATE 680
Value Pricing Feasibility Study

Prepared for the Alameda County Congestion Management Agency
September 2003

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Interstate 680 Value Pricing Feasibility Study

Table of Contents

Lists of Tables and Figures

INTERSTATE 680 VARIABLE PRICING STUDY

EXECUTIVE SUMMARY

Findings

The proposal to utilize planned high-occupancy vehicle (HOV) lanes on Interstate 680 as combined HOV and high-occupancy toll (HOT) lanes is found to be financially, operationally and physically feasible. The recommended separation treatment between the HOV/HOT lanes and the adjacent mixed-flow lanes is solid striping, with limited ingress/egress locations for HOV and HOT users. A combination of electronic toll collection, video surveillance and enhanced highway patrol enforcement would assure an acceptably high level of compliance by HOV and HOT users. The HOV/HOT lane system components could be flexibly adjusted as changes in traffic and economic conditions warrant and could be implemented as a pilot project. Revenues generated from the system could be used for improvements on the corridor, including capital improvements and enhanced transit service. However, implementation involves several challenges, primarily institutional rather than technical.

Background & Purpose of the Study

The Interstate 680 Widening Project is being undertaken by the California Department of Transportation (Caltrans) to address needs in a corridor that has experienced significant and rapidly growing traffic congestion in recent years. The Caltrans project would widen the 14-mile segment of I-680 freeway from Route 84 in the north to Route 237 (Calaveras Boulevard) in the south from six lanes to eight lanes. The Caltrans plan is for the two new lanes to be HOV lanes. An interim southbound HOV lane has been constructed and was opened to traffic in December 2002. The fully widened (Caltrans standard lane and shoulder widths) southbound lane HOV lane is due for opening in early 2007, and the northbound lane will follow at a later date.

The I-680 corridor is characterized by a strongly directional traffic flow, with approximately two-thirds of the morning peak traffic heading southbound and slightly less than two-thirds northbound in the afternoon peak. The peak periods have been spreading to encompass more hours as traffic volume and congestion have grown substantially, up to 4.5 hours in the AM peak. In 2001, when comprehensive data was last gathered, the average trip time was 2.5 times more than would be the case under free-flow conditions.

The purpose of this study, sponsored by the Alameda County Congestion Management Agency (ACCMA), is to determine whether adding a HOT lane feature to the HOV lanes is feasible operationally, financially, and physically. The concept of a HOT lane is to allow otherwise ineligible vehicles to use the HOV lane in exchange for paying a toll. The amount of the toll would vary by time of day and demand, while eligible HOVs would continue to use the lane for free. The potential benefits to using a HOT lane would be: (1) use and manage capacity more efficiently; (2) influence rational transportation decision-making by travelers by linking congestion impacts to value of time; (3) provide a new option for travelers; (4) generate revenues for transportation purposes; (5) provide a demonstration project of road pricing for the region, with the possibility of replicating it in other HOV locations.

HOT lanes are one form of variable road pricing. HOT lanes are currently operating in three U.S. locations (SR 91 in Orange County, I-15 in San Diego, and Houston's I-10 and US 290). Each of those projects has demonstrated the successful combination of HOV lanes with a HOT lane option for those who are willing to pay a toll that varies by time of day and/or traffic conditions. There are more modest forms of variable pricing, with tolls reduced during off-peak hours, in operation in Lee County, Florida, and the New York/New Jersey bridges, tunnels, and turnpike. Internationally, there are a number of locations that have implemented some form of road pricing that is variable by time of day, including Singapore, Norway, Canada, and the United Kingdom.

Most of the international systems are "cordon" schemes, whereby a driver pays a daily fee to enter a center city district during business hours.

Freeway Configuration and Costs

This study looked at a wide range of alternatives at the outset. These included, in addition to the six existing mixed-flow lanes: (1) one HOV lane in each direction (Alternative A); (2) two reversible HOV lanes, one on each side of the freeway (Alternative B), or both in the median (Alternative C); (3) three HOV lanes, one of which would be reversible and in the median separated by fixed barriers(Alternative D); and (4) three HOV lanes, one of which would be reversible in the median, plus one on each side of the freeway separated by a movable barrier (Alternative E). After consultation with Caltrans and the ACCMA, the study eliminated further analysis of the nine-lane and reversible lane options as infeasible in the near-term. All subsequent financial and operational analysis focused on Alternative A, consisting of four lanes in each direction, one of which in each direction would be combined HOV/HOT lane. There will be a buffer space in the range of two to four feet between HOV/HOT lanes and the adjacent mixed-flow lanes; including this buffer is deemed desirable for either HOV-only or HOV/HOT lanes and provides flexibility for future restriping.

The additional cost of changing the freeway configuration for Alternative A to accommodate HOT lanes with an intermediate access location is $4.6- $5.0 million. HOT lanes also require additional toll collection and enforcement costs of approximately $3.2 million capital and $1.0 million for annual operations, but these do not alter the configuration of the freeway.

The key variables studied under Alternative A are:

Lane separation treatments between the HOV/HOT lane and adjacent mixed-flow lanes. Options include: (1) physical barriers; (2) simple striping with buffers between HOV/HOT and mixed-flow lanes; and (3) striping with buffers plus plastic pylons. The simple striping option is recommended at this time, because the physical barrier is considerably more expensive and less flexible than striping. The striping alone is preferred to striping plus pylons, due to the maintenance cost of the pylons and Caltrans safety concerns. The ingress/egress locations can be modified easily by simply changing the striping and adding pavement if necessary. If the HOT lane experiment is not successful, it can be discontinued easily and inexpensively.

Number and location of intermediate access to and from the HOV/HOT lanes. Options include (1) continuous, unlimited access (current configuration of Bay Area HOV lanes); (2) limited access for the entire 14-mile corridor with no intermediate ingress/egress points; and (3) limited access with one or more intermediate access points. Based on preliminary findings, an appropriate location for one intermediate access would be in the vicinity of the Route 262 (Mission Boulevard) interchange, approximately the midpoint of the HOT corridor. Permitting continuous access is problematic for a HOT lane, because it makes enforcement and toll collection more difficult if vehicles can move at will in and out of the HOV/HOT lanes. None of the existing HOT lanes in the U.S. have continuous access. Limited access has the advantage of making tolling and enforcement much easier and apparent to law enforcement. However, it is acknowledged that determined toll evasion is easier than it would be with a solid physical barrier. Limited access would also reduce the number of HOV users of the lanes, because some HOVs would have origins or destinations at a location different from the designated ingress/egress locations.

Effect of carpool eligibility policies. Options include an HOV definition of two persons or more (2+) or a definition of three persons or more (3+) eligible to use the lanes for free. The analysis considers both options.

Toll collection methods. One option is a "placard" system, consisting of a pass or permit purchased periodically (e.g., monthly) for a fixed price and signified by a placard or decal affixed to the windshield. A second option is electronic toll collection, using technology compatible with the FasTrak collection system already in place on the region's bridges, whereby an electronic reader identifies the vehicle from an in-vehicle transponder and deducts the toll from a prepaid account. This study recommends electronic toll collection with a robust collection and enforcement program, including additional highway patrol, extra toll readers and video surveillance cameras for enhanced enforcement and deterrence. Electronic toll collection allows for much more flexibility in adjusting toll levels as needed to assure no overloading of the HOV/HOT lane and substantially more revenue than a permit system. The estimated capital cost of such an electronic collection and enforcement system is approximately $3.2 million, and the annual operating cost is just over $1.0 million.

Financial Feasibility

To determine financial results, optimal tolls were modeled with the goal of maintaining acceptable traffic performance of the HOV/HOT lanes and efficiency in minimizing total delay, in terms of value of time of all facility users (both HOV/HOT and mixed-flow lanes). The analysis used a simplified toll structure with five toll levels, from the highest during peak traffic periods and negligible tolls during night hours. The analysis was done for years 2002, 2006 (the earliest feasible year for implementation of a southbound HOT lane as a pilot project), and 2025. Options with no intermediate access (Alternative A-3) and one intermediate access (Alternative A-4) were analyzed, as were the 2+ and 3+ carpool policies with both access alternatives. The 2+ carpool policy means that all 2+ carpools ride for free and only single-occupant vehicles (SOV) buy in, while 3+ requires SOVs and 2-person carpools to buy in. The key peak and average toll level estimates for 2006 (in 2002 dollars) are shown below:

Toll Rate Estimates for 2006 (2002 dollars)

	Alternative A-3 HOV 2+ No intermediate access	Alternative A-3 HOV 3+ No Intermediate access	Alternative A-4 HOV 2+ Intermediate access	Alternative A-4 HOV 3+ Intermediate access
Southbound AM Peak	$3.13	$4.04	$2.87	$4.84
Southbound AM Peak per mile	$0.22	$0.29	$0.20	$0.35
Northbound PM Peak	$4.62	$5.23	$3.52	$5.29
Northbound PM Peak per mile	$0.33	$0.37	$0.25	$0.38
Average toll (both directions, all times of day)	$0.70	$0.83	$0.59	$0.94

The toll estimates (using constant 2002 dollars) were also forecast for years 2002 and 2025. Forecasts for 2006 and 2025 show higher tolls than 2002, due to traffic growth in the corridor and the resulting increase in the value of time savings accruing to HOT lane users. The 2006 estimates show peak toll level increases in constant dollars, compared to 2002, ranging from 4% to 10%. Year 2025 estimates show peak toll rate increases, compared to 2002, ranging from 41% to 75%. The highest toll level in 2025 is $7.06, which is for the southbound AM peak under the HOV 3+ scenario. The toll levels shown by this analysis are clearly within the range of other existing toll roads in the U.S., including other HOT lanes.

From the standpoint of financial feasibility, it is necessary to show that the HOT lanes generate enough gross and net revenue to justify their implementation. To test this, the financial model calculated the annual gross and net revenues and the cumulative present value of the HOT lanes over a 20-year period for each of the alternatives. The years of operation for this analysis were assumed to be 2006-2025. The net income is equal to gross revenue minus expenses for operation and capital replacement.

Gross and Net Revenues (Millions $) from Southbound & Northbound HOT Lanes

	Alternative A-3 HOV 2+ No intermediate access	Alternative A-3 HOV 3+ No Intermediate access	Alternative A-4 HOV 2+ Intermediate access	Alternative A-4 HOV 3+ Intermediate access
First year gross revenue	9.8	14.1	6.3	14.7
Highest year gross revenue	20.1	27.9	12.3	31.9
Cumulative Present Value of 20-year gross revenue *	159	224	100	245
Cumulative Present Value of Net Income *	142	207	83.0	228

*Based on 4% discount rate assumption.

The overall financial analysis indicates a financially feasible project that would generate substantial net revenues from the opening of the project and steadily increasing net revenues continuing indefinitely. This result is based on conservative assumptions about operating expenses (the most expensive toll collection system) and adopts the Metropolitan Transportation Commission (MTC) forecasting assumption of no assumed inflation-adjusted income growth. If historical trends continue, the assumption of no income growth among users is likely to be an underestimate. If real income actually grows, the real value of time grows accordingly along with the willingness to pay a higher toll. Thus, the gross and net revenue estimates are probably biased downward and are conservative.

Speeds and Travel Times

Under the various scenarios, the average peak-period speeds on the HOV/HOT lanes range from 55 mph to 61 mph, compared to average speeds on the mixed-flow lanes from 25 mph to 34 mph in year 2000. Travel times for HOV/HOT lane users on the corridor segment are reduced by 11 to 19 minutes compared to mixed-flow lane users. By year 2025 traffic congestion worsens, and as a result the speeds are reduced and the travel time savings rise dramatically. The average HOV/HOT lane speeds range from 42 to 59 mph, while mixed flow speeds are between 19 and 25 mph. Travel time savings for HOV/HOT users range from 17 to 31 minutes.

Traffic Volumes and Capacity in HOV/HOT Lanes

Travel forecasting for year 2000 shows peak-hour traffic volumes in the HOV/HOT lanes, including both HOVs and toll-paying customers, ranging from 826 to 1362 vehicles per hour (vph), with volumes in most scenarios falling in the 900-1250 vph range. In year 2025 the peak-hour volumes range from 880 to 1783 vph, with volumes in most scenarios falling in the 1000-1500 vph range. Most scenarios show volume well under the recommended HOV lane maximum of 1600-1700, which are fewer vehicles than the recommended 1900-2200 vph for a regular mixed-flow lane, because there must be an assured higher level of service in the HOV lane. The possible exceedance of the recommended HOV lane maximum volume occurs in one segment of Alternative A-4 under only the 2+ carpool scenario. This finding indicates that, by year 2025, either the 2+ carpool policy would have to be reconsidered or tolls for single-occupant vehicles would have to be raised to a level that causes the number of toll-payers to decline.

Since the southbound HOV lane opened in December 2002, Caltrans has conducted frequent traffic counts. The most recent data show peak-hour counts averaging 541 vph in the HOV lane and 1861 vph in the mixed-flow lanes. Traffic congestion is much less severe, and the mixed-flow lane counts are below those for year 2001, which is likely due to the slumping economy and the recent addition of the HOV lane. It is too early to make any judgments about how much capacity would be available for toll-paying vehicles. The long-term planning for the I-680 corridor will proceed on the assumption that the economy will eventually recover and the severe traffic congestion of the late 1990s will recur and worsen.

Operational Analysis

An operational analysis was performed to determine whether a combination HOV/HOT lane is feasible based on traffic operations. Both the HOV-only and the combined HOV/HOT lanes northbound show bottlenecks at the termination of the lanes, where four lanes funnel into three lanes. These HOT lane constraints can be mitigated and capacity restored by extending mixed-flow auxiliary lanes for short segments (0.5 mile southbound and 1.5 mile northbound), assuming that sufficient right-of-way is available. After the lanes are opened, the volume of vehicles and potential bottlenecks will be closely monitored to determine if and when it is necessary to provide the auxiliary lane.

The combined HOV/HOT lane performs well in most scenarios but results in lower speeds than the HOV-only lane under some scenarios. The reason for lower speeds is the constraint imposed by limited exits from the HOV/HOT lane, creating potential traffic bottlenecks at the few locations available for entering and exiting the lane. Once again, this requires mitigation at the intermediate access location and is, in this case, attributable solely to the HOT lane. The additional capital cost of mitigation for the intermediate access location to alleviate this difficulty with Alternative A-4 is approximately $2.3 million for each direction, or a total of $4.6 million for both directions.

Properly designed, HOV/HOT lanes appear to be operationally feasible and perform comparably with HOV-only lanes in terms of moving people through the corridor. However, the limited access feature of HOT alternatives does remove some of the HOV users who would otherwise use a continuous access HOV lane, because their origin or destination is incompatible with the designated ingress/egress locations.

Policy Considerations

Assuming that I-680 will be widened by two additional lanes, the major decision facing policy-makers is whether to operate these lanes as continuous access HOV-only lanes or as combined HOV/HOT lanes with limited access. There are several policy considerations and questions inherent in the choice:

What constitutes "efficiency" in using the new lanes?

- A major objective of a HOT lane is to gain greater efficiency from the capacity added by new lanes. A HOT lane with restricted access allows underutilized capacity to be used by selling it to users who value the time saving and are willing to pay for it. A HOT lane permits more vehicle and person-throughput in the corridor and removes toll-paying vehicles from the mixed-flow lanes. A HOT lane controls the traffic flow in the HOV flow lane by adding access restrictions to the HOV lane (i.e., limited ingress/egress locations) but at the same time allows more vehicles to enter the lane through pricing and thereby makes better use of existing capacity. The number of toll-paying vehicles in the lane can be controlled by adjusting the tolls upward or downward. The restricted access does cause somewhat fewer carpools on the HOV lane, because of the access location limitations. A reduction in the number of carpools is also possible, because some users who would otherwise form carpools could choose to pay a toll instead; however, actual experience with San Diego's I-15 HOT lanes does not validate this hypothesis. These are issues and trade-offs for policy-makers to take into account.

What is the impact on choices for users?

- A HOT lane clearly provides an additional choice for users, on occasions when saving time is of value to them. On the other hand, a HOT lane system virtually requires limiting access to a few locations, due to toll collection and enforcement considerations. Therefore, the limited access feature – but not the tolling feature – reduces the attractiveness of the lane for carpool users by limiting their ingress/egress choices. While Southern California experience indicates that this is actually not a serious problem, it is a consideration when deciding which access configuration to apply to I-680. Opinion surveys of HOT lane corridor users in southern California have indicated that support has grown for the HOT lane concept since they have been in operation.

What is equitable?

- One equity issue sometimes raised in connection with HOT lane proposals is that higher-income individuals will make much greater use of HOT lanes than will lower-income individuals. While this seems logical, actual experience with existing HOT lanes in Southern California does not bear out that supposition. The income profile of HOT lanes users does not differ greatly from that of the adjacent mixed-flow lanes, though higher-income users do have a propensity to use the HOT lanes somewhat more frequently. Research indicates that low-income individuals place high values of time on some occasions, when being late could be very costly to them. Having the option to pay a toll and being assured reliable time savings can be valuable to persons across the income spectrum. Another equity consideration is making a choice between a direct user fee, paid by a user for making demands on the transportation system during the peak-period, and alternative methods of transportation financing. Some of the other methods, such as sales taxes (unrelated to use of the road) or a per-gallon gasoline tax (unrelated to congestion on a facility or to time of day), might be viewed as less equitable than a user toll that varies in relationship to the burden placed on the transportation system.

What are the impacts on HOV lane design?

- The HOT lane scenarios analyzed in this study necessitate minimal changes in HOV lane design. The limited access feature of the HOT lane does require additional striping and possible design exceptions. In the case of the intermediate access option (Alternative A-4), it requires mitigation by way of a short additional transition or weaving lane. The overhead electronic toll readers and toll-related signage entail some cost, though very little change in design, because they do not require additional right-of-way or pavement.

<u>Evaluating the Alternatives</u>

The various HOT lane scenarios were evaluated in comparison to an HOV-only alternative and against each other. A summary of the evaluation criteria and results follows:

- <u>Corridor travel impacts:</u> The speed data for HOT alternative are mixed, with some scenarios better and some worse than HOV-only. The balance is roughly equal, and it cannot be stated that one or the other has a clear advantage. The same is true with respect to the HOT alternatives compared to one another, except that the 2+ carpool alternatives tended to have higher person-throughput than the 3+ alternatives.

- Operational impacts: The HOT alternatives have slightly negative impacts, due to the limitation of ingress/egress locations and resulting queues at those locations. These impacts can be mitigated with weaving lanes.
- Geometric freeway design: There are no essential design differences among the options, except that the HOT lanes with intermediate access require an additional mitigation lane at the intermediate access location.
- Safety: There is no noteworthy or documentable safety differentiation among the alternatives.
- Tolling and enforcement: This is a mixed result. On the one hand, allowing toll-payers into the HOV lanes complicates visual patrol enforcement by providing two, rather than one, way for a vehicle to be in the lane legally (either as an HOV or a toll-payer). On the other hand, however, there are several reasons why enforcement would be improved for HOT lanes as compared to HOV-only lanes: (1) an electronic signal will indicate to the enforcement officer or automated system that a toll has been collected; (2) enhanced patrol and video surveillance can be paid for by the toll revenue; (3) potential HOV lane violators are given the option to pay a small toll rather than risking an expensive fine. On balance, HOT alternatives are a plus on the enforcement criterion, though not without complication. Among HOT alternatives, those with no intermediate access are somewhat easier to enforce.
- Travel options: All HOT lane alternatives have a clear advantage over HOV-only, because they provide a new option – pay a toll to avoid delay—not otherwise available. The A-4 alternative with intermediate access is somewhat better on this criterion, because it provides additional flexibility. However, the limited access feature of all HOT alternatives does reduce the number of HOVs that might otherwise use an unlimited access HOV-only facility.
- Capital cost: The HOT alternatives each have a moderately higher cost than HOV-only. In the context of the entire widening project these are not high costs: $4.6 for intermediate access and $3.2 million for toll collection equipment. Nevertheless, these costs would have to be funded.
- Revenue generation: HOT lanes are clearly superior to HOV-only lanes, which generate no revenue. The various HOT lane scenarios generate between $6.3 and $14.7 million in the first year, between $12.3 and $31.9 million by the twentieth year, and continue to produce revenue for the full life of the facility. The HOT alternatives with the 3+ carpool policies produce considerably more revenue than the 2+ carpool scenarios, and the A-4 scenario with intermediate access produces somewhat more revenue than A-3 with no intermediate access.
- Net operating income: Once again, HOT lanes generate a positive income stream from the first year, escalating thereafter, while HOV-only lanes generate no income. The cumulative net income over 20 years ranges from $83 million to $228 million and, as with gross revenue, the 3+ carpool policies generate much higher revenue, and the A-4 alternative with intermediate access generates somewhat more revenue than A-3 with no intermediate access.
- Equity: Because equity is subject to numerous definitions, this criterion yields mixed results. From the income distribution standpoint, the more affluent drivers can afford to pay a toll more easily than the less affluent. On the other hand, HOT lanes provide an option for all potential users regardless of income, and only those enjoying the benefit will pay. Furthermore, if revenues are used to improve transit service in the corridor, it makes more transit available to others, including those with lower incomes.
- Transit impact: HOT alternatives have the potential to fund transit service, so they are superior to HOV-only. The only potential negative for transit would be if too many toll-payers were allowed on the HOV/HOT lane and slowed bus service. However, this possibility can be easily avoided by adjusting tolls upward to reduce usage by automobiles.

Conclusions

1. The travel forecasts indicate that adequate capacity on I-680 exists to sustain HOV/HOT lanes as a viable alternative. All near-term scenarios indicate that there will be capacity to allow at least several hundred additional vehicles to "buy into" the planned HOV lanes.

2. I-680 HOT lanes are financially feasible. HOT lanes generate revenue that more than covers the cost of operations, and most scenarios generate substantial excess revenues.

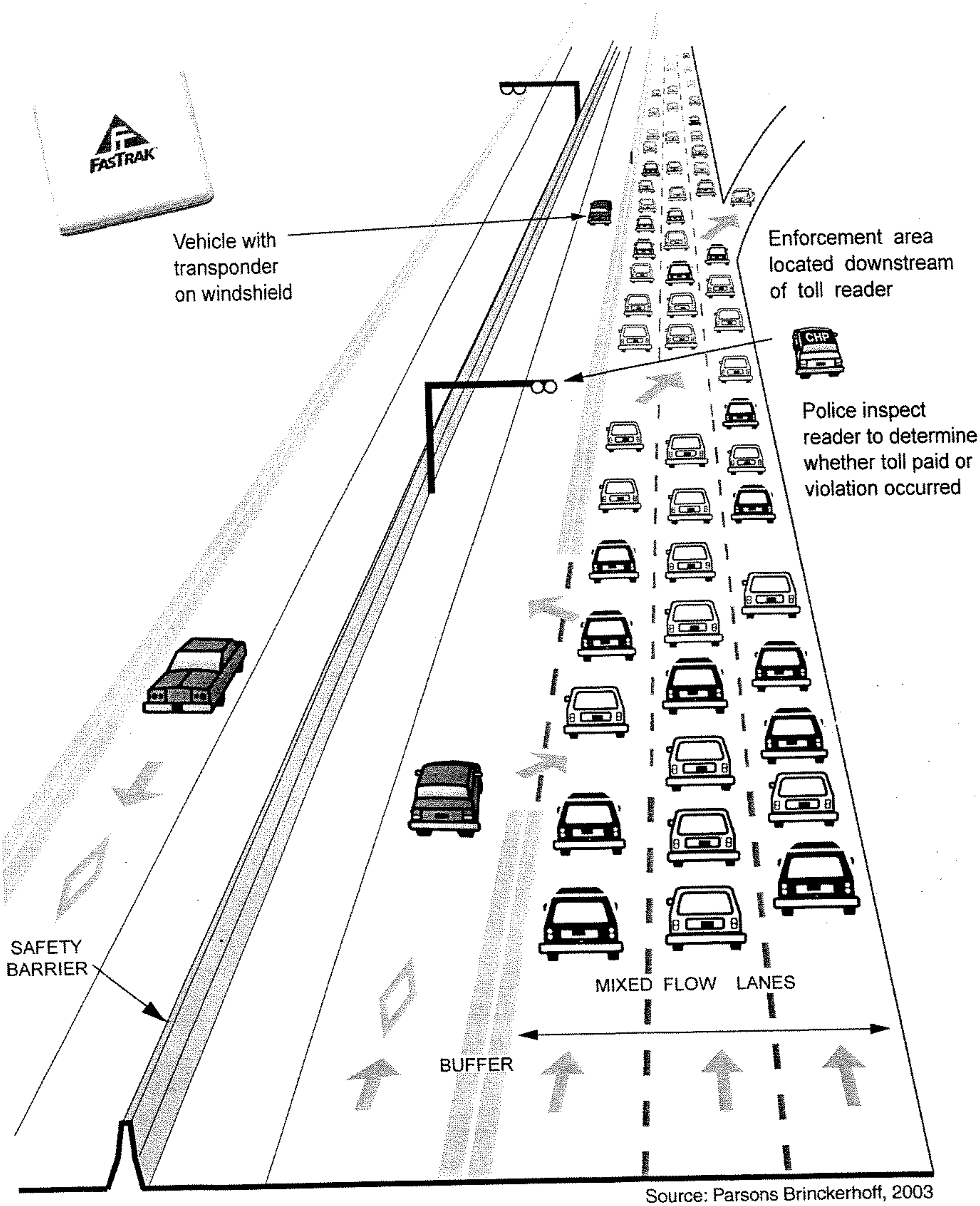
3. I-680 HOT lanes are operationally feasible. Combined HOV/HOT lanes can be operated in a manner that maintains smooth and congestion-free traffic flow on the HOV/HOT lanes without impairing the functioning of adjacent mixed-flow lanes. Potential negative impacts can be largely mitigated by adding transition or weaving lanes at the ingress and egress points of the HOV/HOT lanes. Further coordination with Caltrans and the California Highway Patrol will be done to assure operational feasibility.

4. HOT lanes are compatible with HOV lane operations. Toll levels can be adjusted upward or downward as usage warrants to always assure a high level of service in the HOV/HOT lane. However, the limited access feature does create a complication for HOV users, because they are limited in the locations where they can enter or exit the HOV lane.

5. Enforcement can be maintained at a reasonably high level. A striped lane separation, while less effective than a solid physical barrier, could be well enforced with enhanced highway patrol and electronic collection and surveillance. The study finds that enforcement is likely to be much more effective than the current enforcement of unlimited access HOV lanes. There must be further coordination with the California Highway Patrol to assure adequate enforcement. (The figure on the following page depicts the lane separation, toll collection, and enforcement treatments envisioned for the project).

6. HOT lanes can be implemented with flexibility. With the striped lane separation, it is relatively easy to change the location, number, and configuration of ingress/egress points for the HOV/HOT lanes. If begun as a pilot project in the southbound direction, several options could be evaluated, tested and modified as necessary.

7. Implementation faces major challenges. There are numerous institutional challenges to be addressed before a HOT lane system can be applied to I-680. The concept is new for Bay Area decision-makers and will require interagency cooperation on legal, financial, and operational issues. Specific state legislation will be necessary to authorize the charging of tolls and implementation of HOT lanes on this freeway.



Proposed HOT Lanes Freeway Configration

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CHAPTER 1:
PURPOSE AND NEED

This study considers the feasibility of using a planned high-occupancy vehicle (HOV) lane as a combined HOV and high-occupancy toll (HOT) lane. The following description of Purpose and Need essentially adopts the logic and data from the I-680 Widening Project Study Report and Negative Declaration/Initial Study and FONSI/Environmental Assessment prepared by Caltrans,[1] as it pertains to traffic conditions and justification for highway widening from 6 to 8 lanes. However, it amplifies the statement to the extent necessary to explain the purpose and need for adding the option of pricing to the highway widening concept, in the form of permitting non-HOVs onto the HOV lane in exchange for paying a toll.

I-680 in this segment between Route 84 and Route 237(often referred to as the "Sunol Grade") has experienced a rapid increase in delays in recent years, especially from 1990-2001. As a result of a slowing economy, however, the traffic congestion has been to some degree reduced since this study was initiated in 2001. A majority of commuters on this segment travel from housing located in eastern Alameda, Contra Costa, and the San Joaquin Valley to jobs located mainly in the Silicon Valley in Santa Clara County and southern Alameda County. Peak-period travelers along this segment of I-680 have experienced heavy congestion during the peak period in the southbound direction in the morning and the northbound direction in the afternoon.

The Caltrans study (FONSI, August 2000) show southbound peak period bottlenecks developing by 6 AM and continuing for at least 3 hours. Northbound the peak is approximately from 3:30 PM to 7:30 PM. Travelers are delayed up to an average of 10 minutes daily. The maximum individual delays through this section of I-680 are as high as 33 minutes. The peak mainline demand is estimated to be nearly 8,600 vehicles per hour (vph), while the peak mainline capacity for this section is 6,100 vph. It is projected that the annual number of vehicles will increase up to 95% over the next 20 years. Significantly worse delays are expected due to the increased traffic volumes.

This I-680 widening project proposes to increase the capacity of I-680 within the project limits by adding at least one high-occupancy vehicle (HOV) lane in each direction, and improve operations by adding auxiliary lanes between selected interchanges, widening selected on-ramps, and installing ramp metering hardware at all of the on-ramp locations. By widening the freeway and constructing other traffic improvement elements, it is expected that highway users will experience reduced delays and congestion-related accidents. Caltrans forecasts that the use of the new southbound HOV lane by year 2025 would range between 810 and 1550 vph at various locations during the morning peak hour and that no congestion would occur in the HOV lane.

Most of the existing congestion is attributed to high peak period travel demand. With the addition of new HOV lanes, highway users will have the option to use carpools or express buses to decrease travel time. The addition of HOV lanes will encourage use of alternative transportation modes by providing travel-time savings as compared to mixed-flow lanes.

Caltrans and the Federal Highway Administration (FHWA), in conjunction with the Alameda County Congestion Management Agency, Contra Costa Transportation Authority, and the Santa Clara Valley Transportation Authority, have determined that HOV lanes and associated improvements of auxiliary lanes and improved access to and from local arterials will enhance the efficiency and safety of this segment of I-680. The added lane capacity will improve traffic conditions for all motorists in the corridor, not just the users of HOVs.

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[1] *Negative Declaration/Initial Study (CEQA) Finding of No Significant Impact/Environmental Assessment (, FONSI under NEPA), prepared by California Department of Transportation & U.S. Department of Transportation, Federal Highway Administration. August 2000.*

Value Pricing Lane Goals

The current and projected traffic conditions on this segment of I-680 establish the purpose and need for additional HOV lanes. The concept explored in this Value Pricing Feasibility Study presents an opportunity to manage those additional lanes more efficiently to achieve several purposes:

- Use highway capacity more efficiently
- Influence rational transportation decision-making by individual users through pricing mechanisms
- Provide a choice to travelers that would otherwise be unavailable
- Generate revenues for corridor transportation facilities or services
- Provide a demonstration project in the regional context.

(1) Use and Manage Capacity More Efficiently: Highway capacity is a finite resource, which should be managed to gain maximum efficiency and benefit to users. Assuming additional lanes are constructed, an estimated capacity increase of 1800-2000 vph is available for each new freeway lane, though the capacity for an HOV lane is sometimes defined as the somewhat lower 1600-1700 range (see detailed discussion of "HOV Lane Capacity and Volumes" in Chapter 9 of this report). A HOT lane system offers the opportunity to use this capacity more efficiently, and this study is designed to determine the feasibility of applying the concept on a specific segment of I-680.

Even the most successful HOV lanes in California are often underutilized, and this represents a missed opportunity in taking full advantage of transportation capacity. As HOV lanes, the new I-680 lanes are expected to be relatively underutilized. The Caltrans long-range (year 2025) projection shows that the I-680 HOV southbound lane will be 810-1550 vph.[2] This assumes the continued policy of 2+ person carpool definition; if the carpool definition is changed to 3+ persons, it is anticipated that HOV lane usage could decline drastically, as it has elsewhere when more stringent eligibility criteria are applied. A lack of lane usage can lead to public perception that the lane capacity is wasted and therefore dissatisfaction with the HOV lane concept can grow. In some locations around the U.S., this perception has led to the complete abandonment of HOV lane restrictions and their conversion into mixed-flow lanes.

On the other hand, allowing travelers to "buy into" the HOV lane in exchange for paying a toll is a method for using the excess capacity productively. Single-occupant-vehicles on congested highways can essentially buy excess space on the HOV lane and experience a faster, more reliable trip, without jeopardizing the continued smooth functioning of the HOV lane. Because the price can vary by time of day, day of the week, and even minute-to-minute in "real-time" depending on current traffic conditions, the number of vehicles who will buy into the lanes can be controlled. For example, if an ideal maximum number of vehicles to assure non-congested traffic conditions in the HOV lanes is 1650 vph and the HOV peak flow is 1400, the price can be set to attract no more than approximately 250 vph toll-paying customers; for lower demand time periods, the price would be lower and the number of allowable toll-paying vehicles higher. Variable pricing applies supply/demand economics to available road space in order to manage road capacity for maximum throughput and efficiency.

(2) Encourage Rational Transportation Decision-Making by Individuals: The full cost of an individual trip on a congested road includes not just a traveler's own time and vehicle operating costs, but also the costs that each traveler imposes on all other travelers by adding to the level of congestion. Even though the highway appears to be "free" to the user, the costs are paid in the less efficient operation of the system and delays experienced by others. The addition of HOV lanes on the I-680 corridor will induce some users to form carpools, take mass transit or shift their

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[2] *Ibid. Page E10, Table 7.*

travel to off-peak when the carpool rules are not in effect. This represents rational decision-making by travelers to avoid delay.

Pricing is another tool to encourage travelers to consider the true cost of their trips. A pricing concept could be applied to the new HOV lane capacity on I-680. Individuals who will not or cannot travel in an HOV or shift their travel times can choose to pay a "user fee" to take advantage of the HOV lane for which they would otherwise not qualify. For those users, this represents a rational economic decision that the value of their time (or the value of trip-time reliability) is worth more to them than the toll they pay.

(3) Provide a choice to travelers: While rational economic decision-making by users is valuable to the system as a whole, enhancing the range of personal choice is also an important purpose to be served by variable road pricing. Not all freeway users can arrange their lives to carpool, or at least cannot do so every day. The option to buy into a priced lane provides a new measure of choice, freedom, and security to travelers. Studies of existing priced lanes indicate that many corridor travelers do not choose to pay the toll every day they use the corridor, but only occasionally. While some users are willing to tolerate the delays of congestion rather than pay a toll on many days, there are some occasions when they will want to take advantage of the opportunity to pay to bypass congestion and insure a fast, reliable trip. There are occasions when the cost of being late is too high to tolerate. Knowing that the choice to pay a toll and save time is available can provide a sense of security and control that is not present if the person is captive to whatever traffic conditions prevail on a given day.

(4) Generate revenues for transportation: No other usage of the highway generates any revenues, aside from the normal per gallon gasoline tax. Because automobiles have become more fuel-efficient in recent years, alternative fuel or hybrid vehicles are likely to capture an increasingly share of the auto market, and the gasoline tax generates insufficient revenues to keep pace with transportation needs, other forms of revenue are being given serious consideration. Making a toll option available on HOV lanes generates revenues from users who benefit. Provided that those revenues exceed the cost of collection, the money can be spent to provide other facilities or services that would otherwise not be available. For example, the San Diego I-15 variable pricing revenues are fully earmarked for express bus service in the same corridor. Revenues generated by pricing in the I-680 corridor similarly could be used for bus service, highway maintenance, freeway improvements or any other purpose deemed appropriate.

(5) Demonstration project in the regional context. The Bay Area currently has 285 freeway HOV lane-miles. The MTC's Regional Transportation Plan includes another 240 more lane-miles. It is generally accepted that nearly all new freeway lanes constructed in the region in the foreseeable future are likely to be HOV lanes. Because the Bay Area has committed so many of its resources to existing and planned HOV lanes, it is imperative that those facilities be operated effectively and with public support. I-680 widening presents a near-term opportunity to consider integrating a HOT lane approach into a new HOV lane project from the outset, without the necessity to convert an existing lane from mixed-flow or HOV-only. This may serve as a test case for future HOT lanes.

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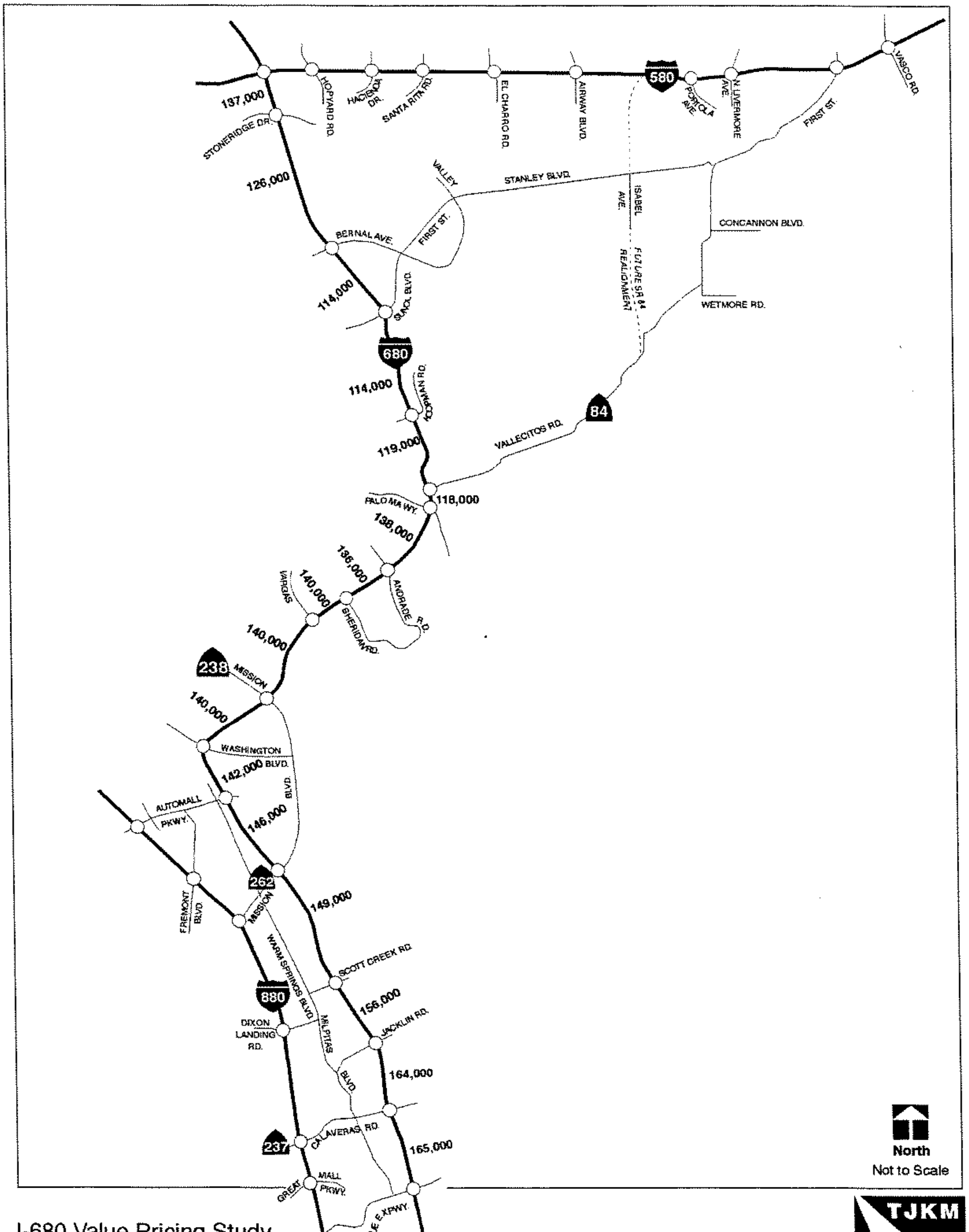
CHAPTER 2:
EXISTING CONDITIONS

Current Volumes

Peak period traffic volumes have increased dramatically in the I-680 Corridor since 1994. By the autumn of 1995, formerly free-flowing traffic became congested over a more than ten mile section from before 6 AM through 9 AM on weekdays. The corridor quickly became the second, and then the first, most congested in the entire Bay Area, surpassing even the Bay Bridge and I-80 in 1999 and 2000. The main cause was the strong job market in southern Alameda County and Santa Clara County (Silicon Valley) coupled with a lack of available housing. Many employees taking jobs in Silicon Valley reside in southern and eastern Contra Costa County, eastern Alameda County and the San Joaquin Valley, due to more affordable housing costs. The I-680 Corridor is the only major route that links the jobs in Silicon Valley with employees living in these areas.

I-680 daily traffic volumes are shown in Figure 2-1. More detailed data, including individual on and off ramp volumes are found in Appendix A. The daily volumes range from 138,000 at the northern end of the study area to 164,000 at the southern end.

Figure 2-1: I-680 Daily Traffic Volumes in 2000



I-680 Value Pricing Study

Study Area Daily Traffic Volumes

TJKM

14-108 - 1/03 - GK

Peak Hour Directional Distribution

Caltrans collected traffic volumes in late 1999 and early 2000 along the I-680 mainline and on- and off-ramps, including peak hour flows by hour by direction. Such information has not been collected systematically over a long period, so long-term trend information for these characteristics cannot be provided. The true directional distribution is a function of both a correction for queuing as well as a correction for peak hour spreading (e.g., the shift of peak hour traffic to other hours due to capacity limitations).

Modeling in the earlier *I-680 Major Investment Study, Phase 2* estimated that the 1998 peak hour directional split in the I-680 Corridor was approximately 66% southbound and 34% northbound in the AM peak hour (total demand = 9,300), and 62% northbound and 38% southbound in the PM peak hour (total demand = 9,600).

Peak period, peak-direction flows on I-680 are typically less than capacity because the traffic is queued. At times along I-680, per-lane hourly flows drop to 1,400 or even less, even though counts show that the per-lane capacity of I-680 is close to the theoretical maximum of 2,200 cars per lane per hour (I-680 north of the Washington Boulevard interchange). This is consistent with the Highway Capacity Manual speed/volume curves that show flows of 1,400 cars per lane per hour occurring both at near the free flow speed for the freeway as well as approximately 20 mph under congested, queued conditions.

Peak Spreading

As commute traffic on highway facilities reaches congested levels, commuters begin to change their travel patterns by either finding less-congested routes or commuting during off-peak hours. This second phenomenon, known as peak spreading, has begun to occur on Bay Area freeways. It is becoming especially pronounced on I-680 for which no uncongested, reasonable alternate routes exist in the study area. The volume sources for these graphs are the Caltrans 2000 volume counts for I-680. The counts are for I-680 north of Mission Boulevard. The graphs below (Figure 2-2) illustrate peak spreading.

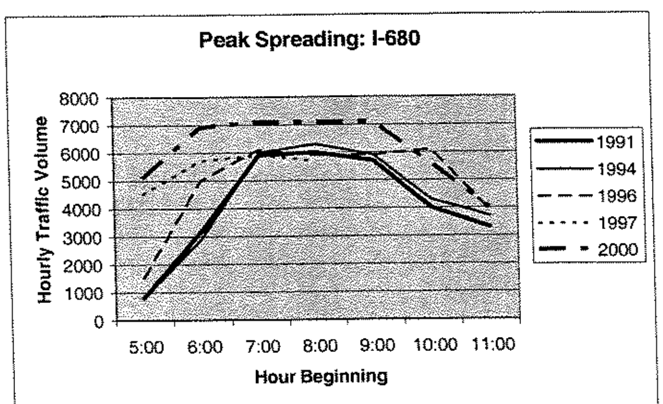


Figure 2-2

On I-680 the southbound AM peak period essentially lasted from 7AM to a little after 9 AM in 1991 and in 1994. The 1996 data indicate the peak had extended well past 10 AM, with traffic volumes also growing during the hour before 7 AM. By 1997 the start of the AM peak was close to 5 AM. Between 1994 and 1997 the I-680 southbound volume between 5 AM and 9 AM increased from 15,854 to 21,698, a 37 percent increase. Essentially all of this traffic growth occurred between 5 AM and 7 AM Note that in 1996 and 1997 the peak hour volumes *decreased* even while the total peak period volumes increased (this is due to increased queuing and congestion in the peak hours with lower corresponding flow rates). I-680 was widened from four to six lanes between 1991 and 1994. In 2000, however, the peak period started before 6 AM and lasted until 10 AM. It is unlikely that the peak will spread much before or after these times, because even commuters with flexible schedules eventually need to get to work before noon, and not much before 6 AM. In the 2000 counts the per-lane flows exceeded 2350 cars per lane per hour in this three-lane section.

Trucks

An earlier analysis[3] indicated that the 1997 volume of southbound heavy trucks, expressed as a percentage of the total southbound traffic volume, tends to increase throughout the AM peak period (even though it decreases slightly as a percentage of the total southbound truck volume). As the *Highway Capacity Manual* indicates, trucks use more freeway capacity than do standard passenger vehicles. The manual includes passenger car equivalents (PCE's) for trucks: one truck equals 3.0 passenger vehicles over rolling terrain (such as the Sunol Grade), and 1.5 over level terrain. Using these factors increases the effective vehicular volume on I-680 by two to four percent in the more level areas, and by sixteen percent over the Sunol Grade.

Average Vehicle Occupancy

Caltrans has counted vehicle occupancy on I-680 since 1998, and the values have not changed noticeably except for PM peak occupancy between 2000 and 2001 in the northbound direction. Vehicle occupancy has been counted on the Sunol Grade in both directions (at the truck weight station). The March 2000 occupancy northbound in the PM peak was 1.36 from 3 to 4 PM, dropping to 1.33 between 4 and 5 PM, and to 1.25 after 5 PM. High occupancy vehicles accounted for 18% of all vehicles. About 40% of all person trips were carried in high occupancy vehicles, including buses and vanpools. Trucks and motorcycles are excluded from all totals. In March 2001 these values had dropped to 15% high occupancy vehicles carrying 27% of all person trips. Average vehicle occupancy is 1.25 from 3 to 4 PM, 1.27 from 4 to 5 PM, and 1.22 after 5 PM.

In the southbound AM peak period, vehicle occupancy is quite low in comparison. Vehicle occupancy in March 2001 was 1.12 from 6 to 7 AM., and 1.09 after 7 AM. About 19% of all person trips are carried in the 8% high occupancy vehicles before 7 AM, dropping to 15% after 7 AM.

In 1997 average vehicle occupancy rates were surveyed and found to be higher than 2001 levels with the AM peak occupancy north of SR 84 approximately 1.25 before 8 AM, and dropping to 1.14 after 8 AM. The occupancy of I-680 northbound at Automall Parkway in March 1997 was found to be 1.35 in PM peak, similar to later Caltrans surveys.

Video surveys were made of commute traffic on I-680 in the AM peak periods in 1998 and 2001. Vehicle occupancy rates on I-680 southbound from the video survey on the Sunol Grade were 1.17 in 1998 with 26% of all person trips in high occupancy vehicles (14% of vehicle traffic). On northbound I-680 in the AM peak period in November 2001, average vehicle occupancy was 1.17 as well.

Southbound AM Peak Travel Times and Speeds

Floating car studies have been performed on southbound I-680 in 1997, 1998 and 2001 during the AM peak period by Caltrans. Figure 2-3 below shows travel times between Stoneridge Way

[3] *Value Pricing Feasibility Study for I-680 Corridor Project. Task 3: Existing Conditions, by TJKM Transportation Consultants. July 2002.*

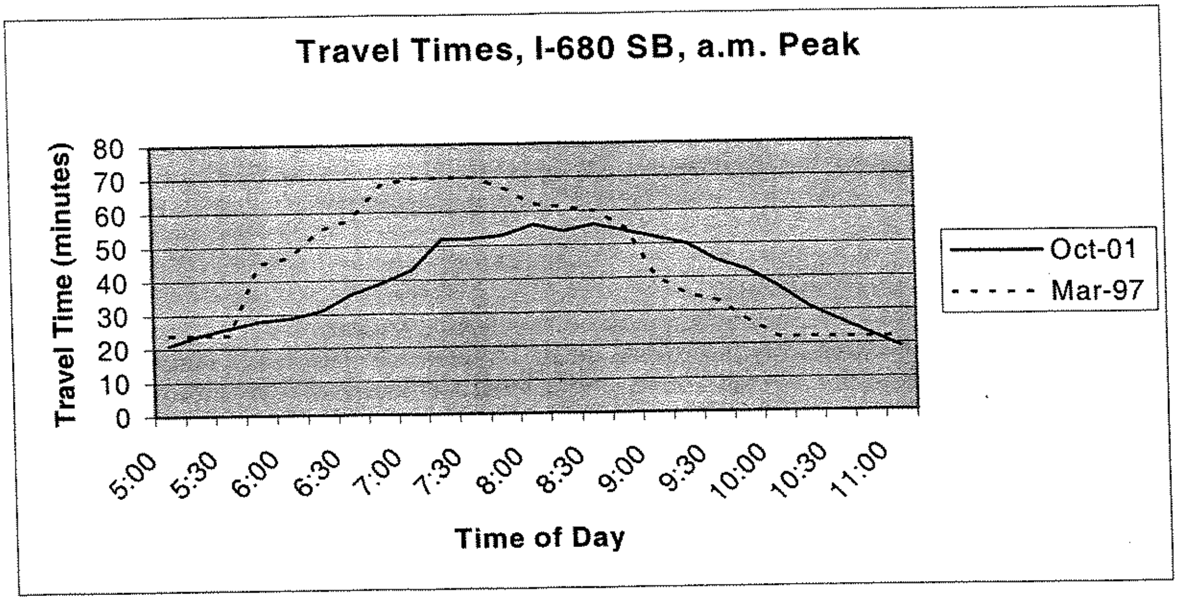


Figure 2-3

in Pleasanton and Calaveras Boulevard in Milpitas for 1997 and 2001. The distance is 20.7 miles, so at 65 mph, the travel time between these two points would be 19 minutes.

The southbound AM congestion is fairly apparent from this graph of the results of 14 runs in 1997 and 22 runs in 2001 between 5 AM. and 11 AM. The maximum time in 1997 was 70 minutes when the survey vehicle started south at 7 AM and 7:15 AM. Maximum travel times in 2001 were 56 minutes for runs starting at 8 AM and 8:30 AM. There is little apparent congestion much before 7:30 AM in 2001 versus 5:45 AM in 1997. In 1997 commuters starting their shift at 6 AM traveling to the NUMMI manufacturing plant in Fremont backed up on Mission Boulevard onto the right-most I-680 southbound mainline lane, thereby reducing the mainline to only two effective lanes for all southbound traffic. Once this queue was started it was maintained through 9:30 AM because as southbound Mission off ramp volumes fell, Mission Boulevard southbound on ramp volumes climbed, which effectively maintained this location as the master bottleneck in the system.

The first phase of I-680 improvements was the southbound auxiliary lane between Automall Parkway and Mission Boulevard. Queued traffic headed to NUMMI can be stored in the auxiliary lane, thus permitting traffic to flow on the three southbound lanes. Traffic continues to flow freely until almost 7 AM. The congested time period lasts from 6:00 AM through 10:30 AM, or four and one-half hours. Congested speeds are essentially travel times of 25 minutes or more (average speeds less than 50 mph, or Level of Service F).

It should be noted that peak period traffic volumes have probably dropped from levels recorded in early2000 when there was booming economic growth and full employment in Silicon Valley. In early 2000 the auxiliary lane had yet to be constructed, and traffic levels were 25% to 35% higher than in 1997. Today traffic levels are still probably higher than 1997 but less than 2000. In the absence of data it is not possible to separate out the influence of the auxiliary lane and the apparent drop in peak period traffic volumes from early 2000. The average AM *peak hour* speed from I-580 to Calaveras is 18 mph.

Northbound PM Peak Travel Times and Speeds

Floating car surveys of northbound PM peak period congestion are less complete than were the southbound surveys. Surveys for northbound PM peak travel times were taken at various times between October 2000 and November 2001. Not all northbound runs were taken for the full length of the route from Calaveras to I-580; most were taken just from Calaveras to Vargas Road at the top of the Sunol Grade, a distance just over 9 miles. Congestion for the entire route is signified by travel times in excess of 25 minutes, as with PM conditions, while congestion for travel times between Calaveras and Vargas are travel times in excess of 11 minutes (speeds less than 50 mph). In an earlier report, *I-680 Major Investment Study, Phase 2* conducted by the Metropolitan Transportation Commission between 1999 and 2001, a calibrated CORSIM model indicated a northbound PM peak hour travel time from Calaveras to I-580 as 44 minutes, or an average speed of 28 mph for the year 2000. Floating car studies for this same route in 2001 indicate a peak hour travel time of 39 minutes. Figures 3-4 and 3-5 below show surveys for the entire route as well as for the 9 mile section from Calaveras to Vargas in 2001. The model output was for the peak hour speed, not the peak period speed. The northbound PM peak traffic congestion is not as severe as in the southbound PM peak for several reasons:

- the queuing back onto I-680 does not occur from the crossing arterial routes,
- north of the SR 238 interchange, more traffic generally leaves I-680 than gets on, so speeds are relatively high north of the Sunol Grade, and
- peaking is less abrupt, and the peak spreading in the PM peak lasts longer than in the AM

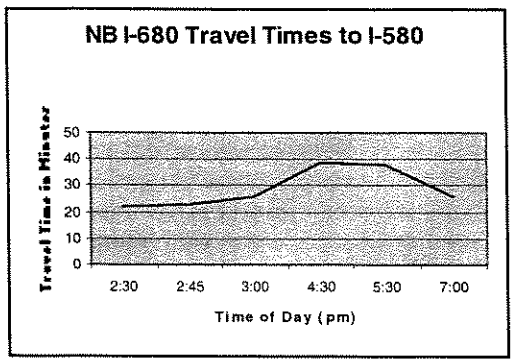


Figure 2-4

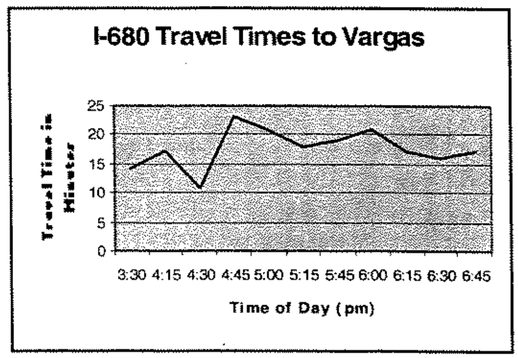


Figure 2-5

Northbound congestion lasts from 3 PM through 7 PM with travel times greater than 25 minutes. Similar results apply for floating car surveys from Calaveras to Vargas as well. Average *peak hour* speeds for northbound I-680 are 32 mph from Calaveras to I-580, and 27 mph from Calaveras to Vargas Road. The average *peak hour* speed in the CORSIM model is slower at 28 mph. The PM *peak hour* average speeds are almost 80% higher than the AM peak hour speeds.

User Characteristics

In addition to the data on volumes and speeds, users were surveyed during the AM peak periods in 1998 and 2001. These surveys were taken using video cameras recording license plate numbers of all cars traveling on I-680 and I-880 at selected points. Surveys were taken in 1998 on the Sunol Grade for AM traffic on I-680, and in 2001 for southbound I-880 north of Automall Parkway and for northbound I-680 south of Montague Expressway. The registered owners of the surveyed vehicles were contacted and asked to return a questionnaire regarding their trip origins and destinations, trip purpose, and other trip characteristics. The detailed results are shown in *Appendix A, Task 3: Existing Conditions.* The most noteworthy result is that the longest average commute distances are clearly on southbound I-680 over the Sunol Grade. An estimate of the average total trip lengths for these users is approximately 34 miles, while average trip lengths for northbound I-680 are approximately 20 miles.

On southbound I-680 94% of all AM peak period trips are home to work related with another 3% of the trips traveling from work to work (most likely truck responses).

For comparative purposes with a nearby parallel route, on Interstate 880 southbound, 90% of all trips were home to work, with 5% for home-based other purpose. The remainder was non-home-based trips to work (3%) and the remaining 2% are other to other. For I-680 northbound 86% of the trips are home-based work related, with an additional 7% home-based other. Another 4% are other-based work related, with the remainder (3%) as other to other. In summary, for all locations the work-related commute trips represent at least 90% of the trip purposes.

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CHAPTER 3:
STATE OF THE ART REVIEW

The Concept of Value Pricing

Transportation policy makers and economists view "value pricing" (also referred to as "congestion pricing" "variable pricing") as one option to address urban highway congestion. The concept applies simple supply-and-demand analysis to transportation economics, using price to signal the value of meeting demand during peak time periods. Of course, many aspects of our economy apply some version of the principle that access to a facility or service should reflect the demand placed on it at different times. Telephone service, for example, charges different rates for different times of day or days of the week. Public power utilities, airlines, hotels, movies, etc. vary their prices by time of day or season – in some cases, seeking to shift demand from peak periods to off-peak, in order to improve efficient utilization of the facility and maximize revenue. Pricing in those contexts seeks to allocate scarce capital assets to meet demand over time. In that sense, road pricing is simply a way to improve the management of limited road capacity.

When roads are uncongested, consideration of road pricing is generally viewed as academic. But in an era when roads are congested and transportation finance insufficient to keep pace with demand, the concept of road pricing becomes more than just an academic exercise. The full cost of an individual trip on a congested road includes not just a traveler's own time and vehicle operating costs, but also the costs that each traveler imposes on all other travelers by adding to the overall level of congestion. A congestion price is a user charge based on a user's perceived cost when entering the traffic stream and the actual congestion cost created by the traveler's entry onto the system. Road pricing can result in more efficient use of limited road capacity by encouraging those who value their trips at less than their full cost to shift to off-peak periods, mass transit, carpooling, and/or less congested routes.

Determining optimal congestion prices exactly is difficult. Estimates can be based on the traffic engineering research that deals with the relationship between travel delays and traffic volume. Analysts have derived estimates of "optimal" congestion prices on the order of 15 to 30 cents per vehicle mile of travel on congested highways and expressways; off-peak prices are in the range of six cents per vehicle mile. However, actual optimal prices could vary widely for each local context, based on degree of congestion, local incomes, availability of alternate routes or modes, etc.

Although the economic theory behind pricing is clear, the actual goals of any real-world project will often be mixed and diverse, including political as well as economic considerations. Goals may include:

- Traffic congestion relief
- Inducement of mode shift or travel-time shift
- Better utilization of existing highway lanes, including "protection" of HOV lanes from conversion to mixed-flow due to public perception of their underutilization
- Justification for new HOV/HOT lane capacity, if HOV demand alone would be insufficient
- Raising revenues to pay for new roadway capacity
- Raising revenue for improved transit service
- Improving air quality
- Encouraging electronic toll collection to improve traffic and collection efficiency

Recent History

Despite its common use in many sectors of the economy, value pricing for roads is a relatively recent practice. Singapore first implemented value pricing in 1975. In the 1990s Norway and France began using variable pricing; in 2003 downtown London began a daytime central city electronic toll collection system; and other countries, including the Netherlands and New Zealand are seriously undertaking pricing projects. In the U.S. a variable-priced toll road opened in late 1995 on a portion of State Route 91 in Orange County, California, and in 1997 on Interstate 15 in San Diego. In 2001 the Port Authority of New York and New Jersey instituted a variable electronic toll structure that gave discounts to off-peak users of metropolitan bridge and tunnels ($5 peak, $4 off-peak for electronic tollpayers, $6 for all cash tollpayers).

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) authorized the Federal Highway Administration (FHWA, a division of the U.S. Department of Transportation) to fund a series of pilot projects using pricing concepts. The program was continued and expanded under the Transportation Equity Act for the 21st Century (TEA-21) in 1998. The objective of these programs is to test and evaluate pricing concepts in a variety of settings nationwide, on an experimental or pilot project basis. Funding was available for both studies and implementation. Studies were undertaken in many regions, including Atlanta, Dallas, Denver, Los Angeles, Miami, Minnesota, Phoenix and San Francisco. A proposal to include a budget and some version of the pricing program is part of the reauthorization process for the successor to TEA-21 in 2003

In the San Francisco Bay Area, federal funds were granted to conduct several studies including the San Francisco-Oakland Bay Bridge Congestion Pricing (1994); Sonoma/U.S. 101 Variable Pricing (1998) and Marin County/U.S. 101 Variable Pricing (1998-2000); and I-880 Value Pricing (2000) and the current I-680 study. Studies also have been undertaken on several corridors in southern California, including SR 57 and SR 91 (extension) in Orange County, I-15 (extension) in San Diego, and SR 14 in Los Angeles County.

Why Pricing Now?

Many recent forces and policy goals have caused transportation authorities to consider value pricing. These include:

- Rapid growth in urban travel demand
- High cost of constructing additional urban road capacity, often in highly constrained rights-of-way
- Environmental or neighborhood objections to roadway construction and expansion
- Availability of new electronic tolling technologies that greatly reduce implementation costs and streamline collection
- Desire for cost-effective strategies to reduce air pollution and energy consumption
- Need for better management of existing or planned facilities, especially those including HOV components
- Need for new transportation revenue sources to build and operate new facilities or services

Although value pricing holds great promise as a way of rationalizing the use of scarce urban road space, many metropolitan areas have been reluctant to implement because of institutional barriers and the lack of political acceptance. Critical political and institutional issues include public opposition to any new fees (especially for roads perceived as having "already been paid for"), geographic and economic equity concerns, lack of regional transportation coordination, and the absence of alternatives to driving alone during peak periods. In many areas, unfamiliarity with any kind of tolling of roads is a major barrier to public and elected officials' understanding and acceptance of the concept. Nevertheless, the problems faced by all other measures to relieve traffic congestion cause pricing to be an option that attracts continued attention.

Different Pricing Concepts

Implementation of congestion pricing may take a number of forms, as illustrated below, but all share the objective of reducing traffic congestion:

- Single facility pricing involving a bridge, tunnel, highway, street, or intersection
- Multiple facility or area pricing by creating a "cordon" around an urban core area or even a regional application (Singapore, London, and Norway examples)

- Single corridor pricing involving a major highway and possibly parallel arterials
- Pricing on new facilities, currently tolled facilities, or on currently free facilities

If the main objective of pricing is to reduce congestion, price levels and differentials between peak and off-peak must be set high enough to have a significant effect on congestion. Projects on existing toll facilities might involve a combination of peak-period surcharges and off-peak discounts. If the main objective is to make more efficient (but not necessarily optimal) use of road capacity, price levels should be set low enough to attract substantial users without generally impairing free-flow conditions on the priced lanes. There obviously are public policy as well as economic considerations in price-setting for use of public roads.

The pricing concept of allowing single-occupant vehicles (SOV) to "buy into" existing, under-utilized high-occupancy vehicle (HOV) lanes is receiving much attention. Typically, free access would be maintained for HOVs and the primary commitment to HOVs would not be compromised. Toll-paying SOVs would be allowed to buy access to the HOV lane with toll rates indexed to the level of congestion. This concept is commonly known as a "high-occupancy-toll" or "HOT" lane. It is essential that a HOT lane fee structure preserve the travel time advantage for the HOV lane relative to the mixed-flow lanes. The current HOT lane examples demonstrate that users are willing to pay a toll to avoid congestion even when there is an adjacent "free" but congested highway alternative, and at the same time there are no adverse impacts on HOV users of the lane.

Examples of Implemented Pricing Projects

1. *State Route 91 "Express Lanes" in Orange County, California.* This 10-mile long privately funded and managed toll facility opened in December 1995. It consists of the four inside lanes of a freeway corridor, two in each direction, which are separated by a pyloned buffer from adjacent lanes. The remainder of the freeway is four lanes in each direction. There are no entrances or exits to the Express Lanes other than at the end points. In January 2003 the private company sold the facility to a public agency, the Orange County Transportation Authority, but the private firm has continued as the facility operator.

The SR 91 freeway is extremely congested during peak commute hours. The SR 91 Express Lanes charge users between $1,00 and $4.75 per trip ($0.475 per mile) depending upon time of day, to reflect the level of congestion delay avoided as compared to the adjacent free lanes. HOVs with three or more occupants were allowed to travel for free from the opening of the facility until January 1998, when a half-price toll charge was instituted. This project is the first fully electronic and automated toll road in the U.S. The Express Lanes priced facility is physically separated from the parallel unpriced freeway by a 4-foot wide painted buffer area. The buffer area includes permanently placed 24-inch plastic traffic pylons placed at 20-foot intervals. The "wall" of pylons makes it difficult for violators to traverse the painted buffer. Two-axle commercial vehicles under 10,000 pounds gross weight are permitted on the Express Lane and commonly observed, but the number using the facility is unknown.

Studies of the SR 91 Express Lanes operations have revealed the following observations:

- While traffic volumes on the facility continued to increase, pricing changes were successful in maintaining free-flow conditions.
- The peak direction Express Lanes carry more than 40% of the total SR 91 traffic, though they constitute only 33% of the SR 91 capacity.
- Travelers were selective in deciding when and under what conditions to use the Express Lanes. About half of the customers used the lanes once a week or less.
- Frequency of use was correlated with income, but there were users at all income levels.
- Female commuters are significantly more likely than male commuters to be frequent users.
- Gross revenues grew from $7.1 million in 1996 to $29 million in 2002. Operating income grew from $733,000 in 1996 to $17.8 million in 2002.

- The annual number of users grew from 5.7 million in 1996 to 9.5 million in 2002.

2. Interstate-15 HOT Lanes in San Diego, California. In December 1996 an existing 8-mile, barrier-separated, underutilized 2-lane reversible HOV facility was converted to high-occupancy toll ("HOT") lanes. At the beginning of the experiment, a limited number of drivers were offered the opportunity to purchase "Express Pass" permits for a monthly fee of $50, which was then increased over several months to $70 due to high demand. The permits allowed a single-occupant vehicle to use the HOV lane during peak hours. The demand for permits far exceeded the number sold.

Electronic tolling was implemented in late 1997, and in 1998 the program began using "dynamic pricing." Dynamic pricing means that, instead of a predetermined toll rate, the rate fluctuates according to the amount of traffic actually on the road during that particular time of day. An electronic message board displays the fare to drivers at the entrance. The average peak-period price is approximately $4.00 ($0.50 per mile), though on rare occasions (usually when a serious traffic incident caused severe congestion) the price has gone as high as $8.00, the maximum allowed. HOVs continue to ride for free. By the nature of the reversible operation, this roadway is separated from adjacent lanes by permanent concrete barriers, with ingress and egress only available on either end. Two-axle commercial vehicles are permitted on the HOT lanes. There are approximately 50 commercial accounts among the 10,000-member account base, including some major fleets such as UPS and the U.S. Postal Service. Extending the I-15 Express Lanes for an additional 10 miles, with intermediate access locations, is under serious consideration.

According to surveys of Express Lane toll users, they have the following demographic characteristics, compared to general-purpose freeway lane users: higher incomes, predominantly in the 35-54 age range, homeowners, two-vehicle households, and more likely to be female. Their average per week trips using the Express Lanes was between 4.6 and 5.3 in the surveys taken over a 2-year period. Among current paying users, 88% and over two-thirds of other I-15 users support the existing HOT lanes.

3. Quickride - Katy Freeway, Houston, Texas. Similar to the San Diego program, in January 1998 the Metropolitan Transit Authority and Texas Department of Transportation (TXDOT) opened a 13-mile reversible, barrier-separated HOV lane on the Katy Freeway (Interstate 10) to two-person carpools for a fee during the most heavily congested AM and PM peak hours. Ingress and egress are at either end of the HOV lane (no intermediate access). Carpools of three or more ride for free, and single-occupant vehicles are not eligible to use the lane. Previously, carpools of two or more were permitted to ride for free, but the policy was changed to three-plus to reduce traffic on the HOV lane due to overcrowding by two-person carpools. The "Quickride" lane uses windshield transponders to charge $2.00 per trip ($0.20 per mile). Three-plus carpools continue to ride for free. The reversible HOV/HOT lane is separated from the mixed-flow freeway lanes by three-foot high concrete barriers. Houston extended the Quickride application to another HOV lane facility on US 290, also allowing two-person carpools to buy into the lane.

4. Lee County, Florida. The Florida Department of Transportation installed electronic toll collection on two existing toll bridges and offers a 50 percent discount for use during non-peak traffic hours. Under the pricing plan, a 50 percent toll discount is provided for trips made during the half-hour period before the morning peak (7:00 – 9:00 AM) and in the two-hour period following the morning period. In the evening, the discount period is two hours before the evening peak (4:00 – 6:30 PM) and one-half hour after the peak. The pricing strategy has caused drivers to shift trips to the shoulders of the peak, leading to improved service for bridge users. Lee County is now considering a priced "queue-jumping" lane.

5. New York/New Jersey Toll Bridges and Turnpike. In March 2001 the Port Authority of New York and New Jersey instituted variable pricing for all bridges and tunnels between the two states. The price variations were available only to users of electronic toll collection equipment. The policy had a dual purpose: (1) Encourage use of electronic transponders to ease collection and improve traffic flow; (2) Encourage a shift in travel from the peak-period into the shoulder or off-peak. The toll structure is: $4 off-peak, $5 peak, $6 for cash payers. Preliminary indications showed a modest shift (about 4-7%) shift from peak to off-peak trips, but a significant increase (from 46% of transactions before variable pricing to 79% after) in the use of electronic toll technology and in carpool transactions (21%). The New Jersey Turnpike instituted a similar program with slight discounts for off-peak periods. Analysis is underway to assess the long-range impact of these programs.

In addition to the implemented projects there have been a number of pre-implementation studies done around the nation. They include major studies in the San Francisco Bay Area, Santa Cruz, Minneapolis, Los Angeles, New York City, Colorado and Oregon.

Furthermore, in February 2003 the Reason Foundation issued a report advocating a nationwide network of HOT lanes. [4] The Reason Foundation proposal postulates a HOT lane network in ten major metropolitan areas, including conversion of existing HOV lanes and new facilities to HOT/Bus Rapid Transit lanes. While much more comprehensive and not directly comparable to the analysis in this I-680 Variable Pricing report, it is interesting to note that the Reason Foundation's peak direction toll calculated for the entire San Francisco Bay Area is 38 cents/per mile, which is very close to the per mile peak toll level shown by the analysis for I-680 HOT lanes in Chapter 8 of this report.

Lessons Learned

A number of instructive lessons have been gleaned from the several projects that have been implemented and the many projects studied but not yet implemented:

1. *Difficulty of Implementation.* Severe traffic congestion and/or relatively underutilized HOV lanes are conditions conducive to consideration of a HOT lane in a given corridor. However, those conditions are far from sufficient to give a HOT lane a high likelihood of implementation. This is a difficult concept to put into practice, no matter how theoretically logical it may appear to traffic engineers or economists.

2. *Need for a champion.* In those cases where a HOT lane has been implemented, there was a strong political or institutional "champion" of the project. In those much more numerous cases where the concept has been studied but shelved, there has generally been relatively little overt opposition to the idea, but neither the business community nor elected officials demonstrated great enthusiasm or a sense of urgency about pursuing implementation. This meant that there was no driving force to push the project forward or overcome skepticism and the inertia of the *status quo.* Even where there was a state legislative mandate to implement pricing on I-25 in Denver, Colorado, local opposition for reasons unrelated to the concept of pricing has been enough to stall implementation.

3. *Diverse motivations are at work.* The motivation for projects that have been successfully implemented has been, at least in part, something other than a desire to allocate road capacity efficiently. In the case of SR 91, the private toll franchise was awarded as a result of frustration about delays in financing additional freeway capacity for a corridor where there was severe congestion and a public demand for more capacity; so private investment was sought, and the investor realized that a variable toll structure made the most sense economically. In the case of the New York/New Jersey bridges and tunnels, the motivating factor was at least as much to encourage use of electronic transponders to ease collection as it was a desire to test the impact of variable pricing.

[4] *HOT Networks: A New Plan for Congestion Relief and Better Transit, by Robert W. Poole, Jr. and C. Kenneth Orski, February 2003.*

4. *Availability of excess road capacity is crucial.* The presence of significant excess road capacity is critically important. If the HOV lane is already heavily used and near capacity, there will be serious concerns about selling the remaining excess capacity. If decision-makers perceive that there might be a significant demand for HOV capacity in the future and therefore little or none available to sell, they will be reluctant to take a chance on embarking on a HOT lane program. On the other hand, if there is substantial HOV lane capacity but still not substantial time savings to be gained during peak hours in using the HOV lane, then SOVs will be reluctant to pay for the use of the capacity. The ideal situation for a HOT lane is constant, heavy congestion for several hours in mixed-flow lanes, adjacent to relatively empty HOV lanes.

5. *Intermediate access issues complicate the design.* The HOV/HOT lane design with only one entrance and one exit is simpler to implement than a design with multiple intermediate access points. Frequent or continuous access and egress greatly increases the complexity of managing and enforcing a HOT lane. Issues of effective toll collection, enforcement, and separation between mixed-flow and HOV/HOT lanes are raised whenever intermediate access is a possibility. To date, the only HOT lanes in operation have no intermediate access.

6. *Revenues can vary widely.* Depending upon the degree of congestion, time savings, reliability, and form of pricing, revenue potential can be lower or higher. The ideal situation for maximum revenues is substantial and reliable time savings, and highly variable pricing, preferably dynamic on a real-time basis, to reflect actual traffic conditions. A low-tech, permit system is likely to produce far less revenue than electronic tolling, though it is also less expensive to put into place. The San Diego I-15 experience of starting with permits to introduce the concept and then shifting to electronic toll collection with dynamic pricing is a model of low-risk but ultimately successful implementation.

7. *Enforcement can be complex and can be expensive.* When the highway patrol is contracted to be the principal means of enforcement, the patrol officers generally regard this task as a distinctly secondary part of their duties. Video enforcement, on the other hand, can be quite expensive and lacks the immediate deterrent impact of a traffic stop and citation, both on the violator and on other potential violators. Enforcement is easier when there is no intermediate access to the HOT lane. Nevertheless, the HOT lanes currently in operation do experience very low violation rates and high levels of customer and operator satisfaction.

CHAPTER 4:
ALTERNATIVES

Project Background

This chapter investigates design concepts for providing HOV and HOT lanes on the I-680 corridor from Route 84 to Route 237 (Calaveras Boulevard) in Santa Clara County for a total length of approximately 14 miles (22.4 kilometers). Currently, I-680 within these limits provides a 6-lane facility with three through lanes in each direction, plus one interim, non-standard HOV lane in the southbound direction from Route 84 to Route 237. Whatever HOV lane configurations are considered dictate the HOT lane options, because all HOT lane options simply permit toll-paying vehicles on what would otherwise be solely HOV lanes.

Caltrans is planning to widen I-680 to provide one standard HOV lane in each direction. I-680 within the above limits is frequently congested during the commute hours and with the anticipated future travel demands, the traffic growth will further the duration and length of congestion along the corridor. An interim southbound HOV lane was opened in December 2002, and construction bringing the southbound lane up to full freeway standard is expected to be completed in 2007. Caltrans is currently preparing an environmental document (EIS/EIR) for the northbound widening.

The currently funded southbound improvements are being implemented in several phases. The environmental document for the southbound HOV was approved in September 2000. The initial phase constructed an auxiliary lane between Mission Boulevard and Automall Parkway. This phase opened in early 2001. The second phase, completed in December 2002 and now open to traffic, constructed shoulders to allow for an interim HOV lane from Route 84 to Route 237. The next phase will construct most of the proposed soundwall in the corridor. The final phase will widen structures and shoulders to final roadway width for HOV and additional auxiliary lanes. Ramp metering is included in this phase.

The corridor traverses through both flat and rolling terrain within the study area. Of the 14 miles of the corridor, about 6.4 miles provide separate grades (split grades) between the northbound and southbound roadway sections at various locations.

HOV lane cross-sections vary depending upon the design and size of existing overcrossing structures and/or the location of columns in the median.

Following are summary descriptions of the basic alternatives that have been under consideration by Caltrans in its environmental study, plus a summary of advantages and disadvantages of each. The lane configurations and lane separation characteristics are depicted in Figures 4-1 through 4-6.

Alternative A-1: HOV-only, continuous access.

This is the basic widening to add one HOV-only lane in each direction (Figure 4-1). There would be no HOT vehicles permitted in the lane. Access to and from the lane from adjacent mixed-flow lanes is continuous and unlimited. This describes most HOV lanes currently in operation in the San Francisco Bay Area region, and it represents the "base case" for the study.

Alternative A-2: HOV/HOT, continuous access

The first HOT lane concept (also Figure 4-1) included in this assessment is utilization of the basic HOV project for one HOV/HOT lane in each direction, with no reversible lanes. There is no physical barrier between the HOV/HOT lane and the adjacent mixed flow lane, nor is there any other limitation on access at any location through striping or otherwise. Little modification of the current HOV-only plan is necessary to incorporate a HOT concept on this project.

Advantages:
- Low cost alternative and easy to implement (no physical barriers or additional right-of-way)
- Continuous HOV ingress and egress access provided for the entire length of the project

Disadvantages:
- Without physical or buffer separation of HOT lanes from general purpose lanes, toll collection and enforcement become much more difficult.
- Unlimited opportunity for weaving between HOV/HOT lane and mixed flow-lanes throughout the facility

Alternative A-3: HOV/HOT, limited access, solid yellow striping,

This alternative (Figure 4-2) would separate the HOV/HOT lanes from the mixed-flow lanes with a two-to-four-foot buffer zone with solid double yellow stripes. Ingress to and egress from the HOV/HOT would be limited to only one entrance and one exit for the entire 14-mile freeway segment. The barrier to limit crossing to and from the HOV/HOT lane would be depicted on the pavement by solid double yellow stripes, as well as reinforced by signage.

Advantages:
- Low cost alternative
- Can be easily modified to move location of ingress/egress if traffic operations require
- Easy for emergency and law enforcement vehicles to access HOV/HOT lanes and shoulders

Disadvantages:
- Limited access locations for HOV users could discourage some HOVs from entering.
- Without physical separation of HOT lanes from general-purpose lanes, toll collection and enforcement are more difficult than it would be with a positive physical barrier.

Alternative A-4: HOV/HOT, one intermediate access, solid yellow striping.

This is identical to A-3 (also Figure 4-2), except that that it provides at least one intermediate ingress/egress location approximately halfway through the 14-mile freeway segment. Changing the location of the intermediate access point, or adding more intermediate locations if traffic patterns warrant, would be easily accomplished by restriping under this alternative.

Intermediate access could be provided at any appropriate location along the freeway segment. The most plausible location appears initially to be at the Route 262 (Mission Boulevard) interchange, because there is significant on/off activity at that interchange. However, the location of intermediate access is subject to further analysis. Intermediate access is applicable to all of the other Alternatives below, except for contra-flow lanes.

Advantages:
- Low cost alternative
- Can be easily modified to move location of ingress/egress if traffic operations require
- Easy for emergency and law enforcement vehicles to access lanes and shoulders

Disadvantages:
- Limited access locations for HOV users could discourage some HOVs from entering.
- Without physical separation of HOT lanes from general-purpose lanes, toll collection and enforcement are more difficult than it would be with a positive physical barrier.

Pylons plus striping

Another variation for lane separation in Alternatives A-3 and A-4 is the addition of an additional form of lane separation to simple striping. Besides solid striping, the HOT/HOV lanes could be separated from the mixed-flow lanes with a buffer zone that includes plastic pylons placed approximately every 20 feet. Similar to striping-only, ingress and egress would be limited to only one or two locations and would be depicted by the absence of pylons, breaks in the striping, and signage. Pylons are easily damaged, however, and need to be replaced at a high rate, so costs and safety complications in maintenance must be taken into consideration.

<u>Advantages:</u>
- Low cost alternative, compared to physical barrier
- More effective than striping alone to deter to lane-crossing and toll evasion

<u>Disadvantages:</u>
- Limited access locations for HOV users
- High cost and safety issues in maintaining plastic pylons

ALTERNATIVE B

Under this alternative (Figure 4-3), the northbound and southbound HOV lanes will both serve HOV and HOT vehicles traveling south in the AM peak hours and traveling north in the PM peak hours. The contra-flow lanes will be provided by use of <u>movable concrete traffic barriers</u> for the southbound AM HOV and northbound PM HOV lanes. During off peak periods, the movable barriers would be placed next to the median barriers. On the low side of split sections, where no median barrier exists, the movable barriers would be placed at the edge of the shoulder.

Access will be provided only at the beginning and end limits of the project in the direction of the contra-flow lane, though the other direction with the concurrent, mixed-flow lane could have intermediate access.

Each of the proposed HOV and HOT lanes will provide 12-foot (3.6 meter) standard lane width; however, shoulder widths ranging from minimum to standard widths are proposed. The proposed minimum shoulder widths will require approval of Caltrans design exceptions.

<u>Advantage</u>
- Two lanes of HOV/HOT capacity for peak period traffic

<u>Disadvantages:</u>
- Moveable barrier placement and removal make one lane at least partially unavailable for traffic during the barrier placement and removal operations.
- Contra-flow lane provides no intermediate access at any time.
- High capital and operational costs, compared to striping/pylon separation treatments

ALTERNATIVE C

Under this alternative (Figure 4-4), a two-lane center section with fixed barriers on both sides accommodating the reversible traffic will be constructed, similar to I-15 in San Diego. Because of long weaving section requirements along the freeway for ingress and egress, it would not be possible to create frequent openings along the fixed barriers and provide access to all interchanges along I-680. This alternative operates best with the least number of ingress and egress locations to provide simple freeway and HOV and HOT operations. One intermediate ingress and egress area might be included where most HOV/HOT demand is anticipated, possibly at Route 262/Mission Boulevard.

Similar to Alternative B, the traffic would travel south in the AM peak hours and north in the PM peak hours and transition tapers will be constructed at the beginning and end of the project. It will include two standard 12-foot lanes.

Advantages:

- Two lanes of HOV/HOT capacity in peak period traffic
- Potentially safer and more permanent solution to higher design capacities
- Low comparative operating cost
- High degree of control in lane access, resulting in effective enforcement.

Disadvantages:

- High capital cost
- Fewer ways to gain access into and out of the lanes, less flexibility

It is also possible to mix and match Alternatives B and C. An example of such alternative would be a two-lane fixed barrier (Alternative C) from the northern limit of the project to Route 262 and the moveable barrier (Alternative B) from Route 262 to the end of the Project at Route 237. The final configuration would depend on a HOV demand, and egress and ingress analyses.

ALTERNATIVE D

Under this nine-lane alternative (Figure 4-5) a one-lane center section with fixed barriers on both sides accommodating a reversible traffic lane is added to the basic 8-lane freeway widening. The remainder consists of one conventional HOV and three mixed-flow lanes in each direction. The one-lane reversible center section will accommodate a combined HOV/HOT or an exclusive HOT lane and can be designed either with ingress and egress only at each end of the corridor, or with intermediate access. It will include a standard 12-foot lane, and a total inside and outside shoulder width of 10-foot and two concrete barriers. The direction of the lane will be switched twice per day, once before the AM peak begins and once before the PM peak begins.

Advantages:

- Continuous HOV ingress and egress access for the entire length of the project in the non-reversible HOV lanes, allowing maximum flexibility for HOVs
- More capacity to accommodate higher anticipated demand
- Low operating cost, compared to moveable barriers
- High degree of control in lane access, resulting in effective enforcement

Disadvantages:

- HOT lane access is limited.
- High comparative capital cost

Alternative E

This nine-lane alternative (Figure 4-6) uses a moveable barrier on one side of the freeway median to reverse the direction of the ninth lane to accommodate the peak flow. During the morning peak the barrier is stored directly adjacent to the median and the fifth southbound lane (the ninth lane) is used as a HOT or HOV/HOT lane. During the PM peak the moveable barrier is placed outside the fifth southbound lane and becomes a contra-flow lane in the northbound direction.

Advantages:

- HOV ingress and egress access provided continuously for the entire length of the project in the non-reversible HOV lanes
- More capacity to accommodate higher demand

Disadvantages:

- High capital cost, compared to striping/pylon separation treatments
- High operating cost due to movable barrier

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Alternatives A-1 & A-2 – AM & PM Peak (Continuous Access)

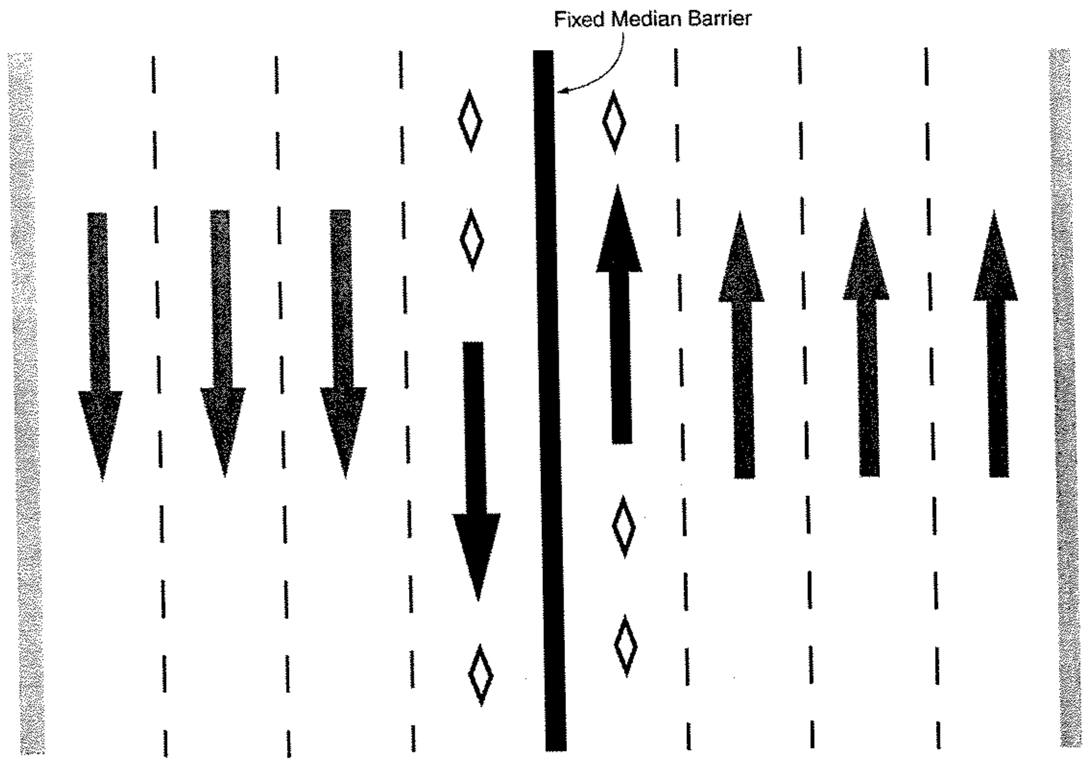


Figure 4-1

Alternatives A-3 & A-4 – AM & PM Peak (Limited Access)

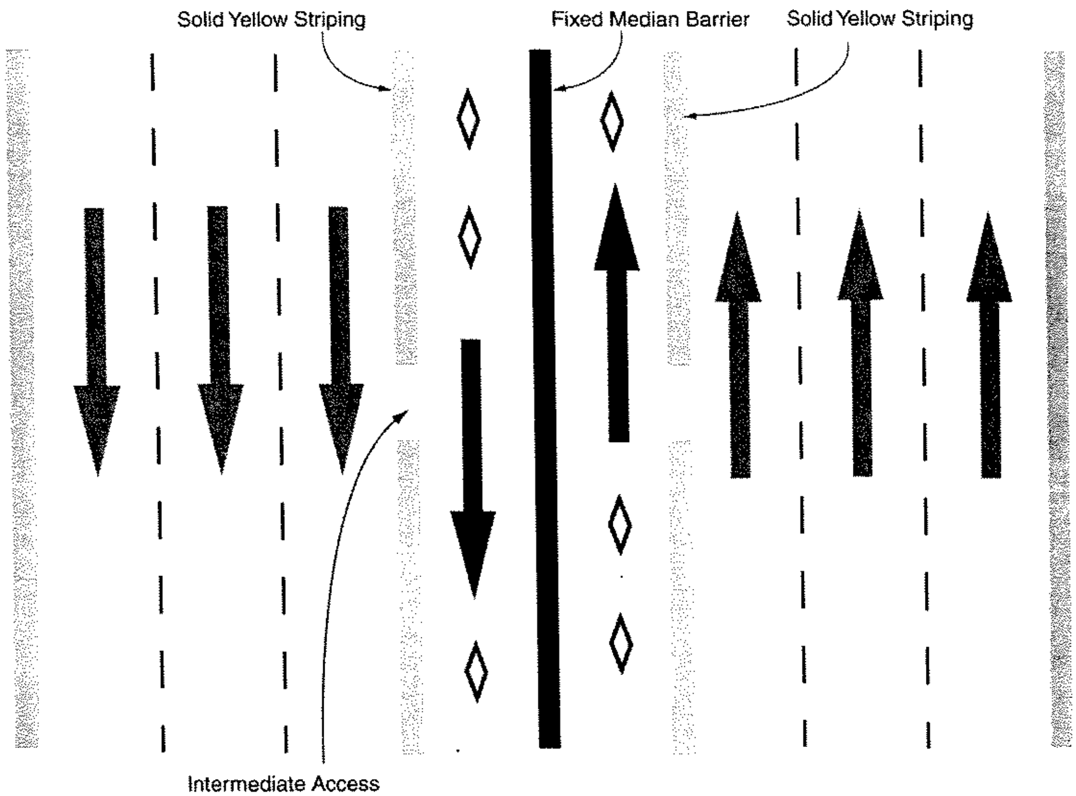
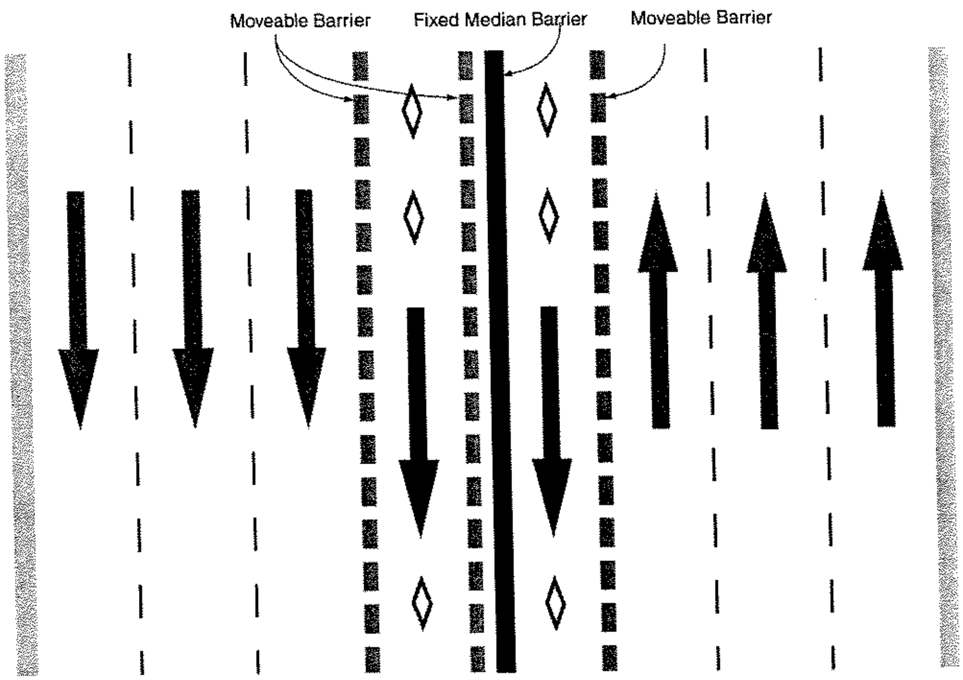


Figure 4-2

Alternative B – Reversible: AM Peak



Alternative B – Reversible: PM Peak

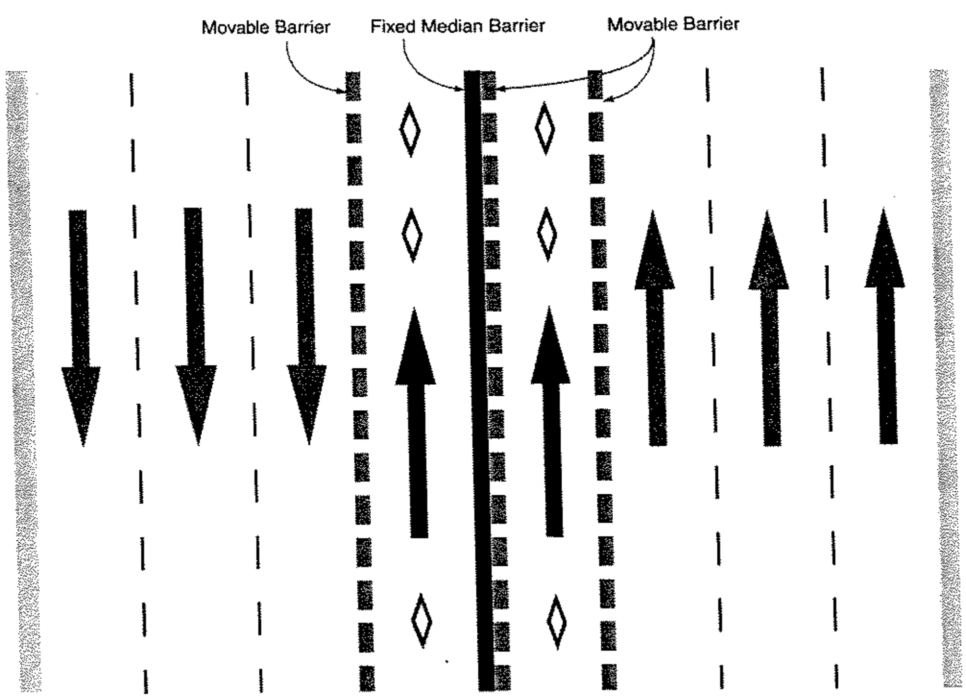
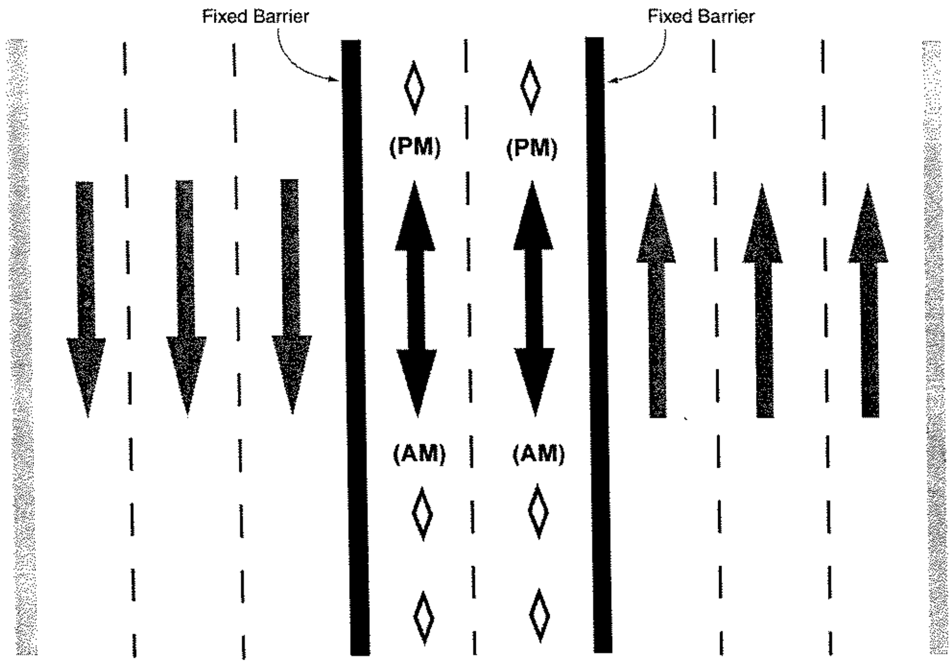


Figure 4-3

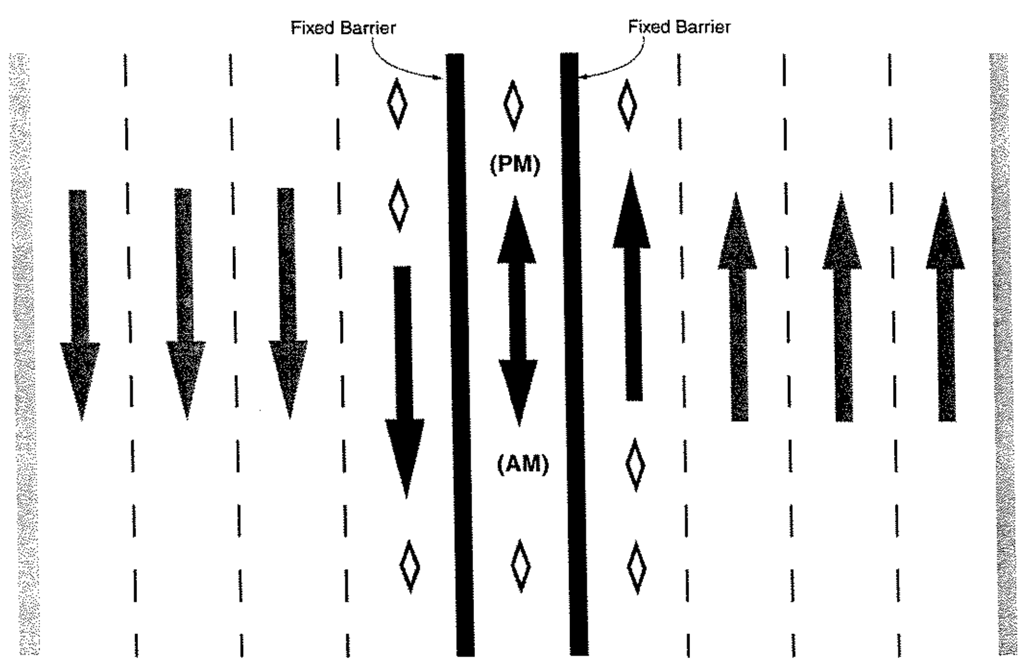
Alternative C – Reversible



I-680

Figure 4-4

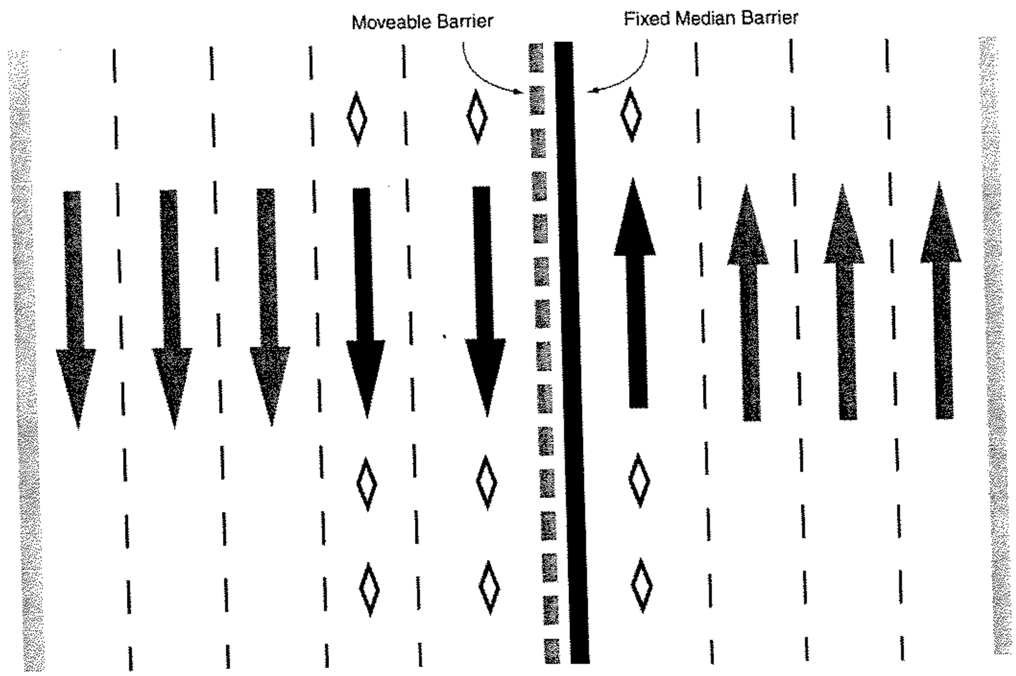
Alternative D – Reversible (9 lanes)



I-680

Figure 4-5

Alternative E – Reversible: AM Peak (9 lanes)



Alternative E – Reversible: PM Peak (9 lanes)

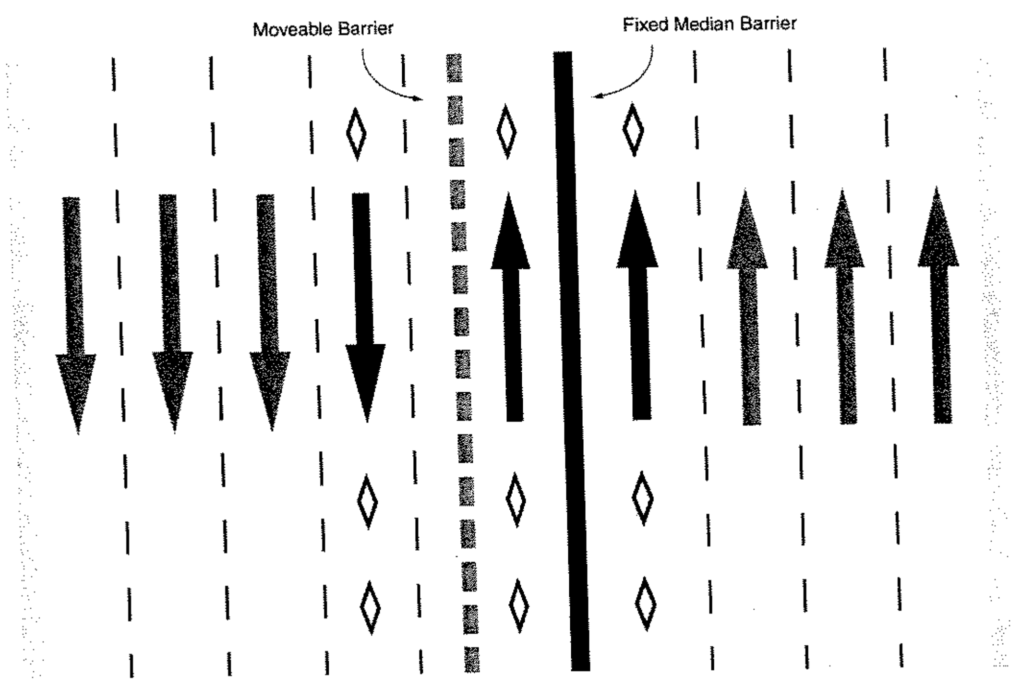


Figure 4-6

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Table 4-1
Comparison of Alternatives

Alternative	HOV/HOT Lanes	Direction NB=north-bound SB=south-bound	Reversible	Lane Separation Treatment	HOV/HOT Lane Location	Inter-mediate Access Locations
A1 Continuous access	2 HOV-only	1 NB 1 SB	No	None	1 on each side of current median	Continuous
A 2 Continuous access	2 HOV/HOT	1 NB 1 SB	No	None	1 on each side of current median	Continuous
A 3 Limited access: striping	2 HOV/HOT	1 SB 1NB	No	Solid yellow striping	1 on each side of current median	0
A 4 Limited access: striping + pylons	2 HOV/HOT	1 SB 1 NB	No	Solid yellow striping + pylons	1 on each side of current median	1 or more
B	2 HOV/HOT	2 SB – AM 2 NB - PM	Yes	Moveable barrier	1 on each side of current median	0 in contraflow direction; 1 or 0 in other direction
C	2 HOV/HOT	2 SB - AM 2 NB - PM	Yes	Fixed barrier	2 in current median	1 or 0
D	2 HOV 1 HOT/HOV	2 SB/1 NB-AM 1 SB/2NB - PM	Yes	Fixed barrier	1 in current median	1 or 0
E	2 HOV 1 HOT/HOV			Moveable barrier	2 on west side of median; 1 on east	0 in contraflow direction; 1 or 0 in other direction

Approaches to selection of HOV/HOT Access

There are two distinctive approaches to selecting a HOV system in terms of access requirements: continuous versus limited access. The selection between these access options is one of the most critical decisions to be made by policy-makers and it affects the feasibility of the project.

Contiguous lanes/continuous access:
Under the continuous access system, HOV users are free to enter and exit the HOV lane from the adjacent mixed-flow lane at any location. The continuous alternative is normally associated with the HOV systems in northern California and requires no additional capital cost. However, there are two disadvantages to this system. First, the unlimited ingress and egress by all vehicles to and from the HOV lane can create excessive weaving and operational problems within the adjacent mixed flow lanes and can impact the level of service in both the mixed flow lanes and the HOV/HOT lane. The problem is further exacerbated when the interchanges along the corridor are closely-spaced, meaning that weaving will be constant. Second, enforcement is difficult, as users are free to enter and exit the HOV lanes as they wish. Violators have an incentive to exit the HOV lane quickly in order to avoid detection, especially if they spot a highway patrol car in the vicinity.

Limited Access:
With the limited access system, users are restricted and must enter or exit only at specific, marked locations. This access system is widely used in southern California. There are numerous examples, including HOV lanes in Orange County (I-5, I-405, SR-55, SR-57 and SR-91) and Los Angeles County (I-10, 1-105, I-405, SR-14, SR 118, etc.) and I-15 in San Diego. The limited access system works best when a large number of the users travel the entire corridor as a "pipeline." There are two variations for this system: (1) separation by a physical barrier, and (2) buffer separated by means of striping. The striped buffer is the separation treatment for most of the Southern California HOV corridors. Limited access offers improved traffic operations in both mixed-flow lanes and the HOV/HOT lanes by reduced weaving. The disadvantage of this system is the congestion at the ingress and egress points when high volumes of traffic seek to enter and exit the HOV/HOT lanes. Normally, mitigations such as addition of ingress/egress weaving lanes (Figure 4-7) at these locations are advisable.

Intermediate Access
Ingress / Egress at Buffer Separated HOV/HOT Facilities

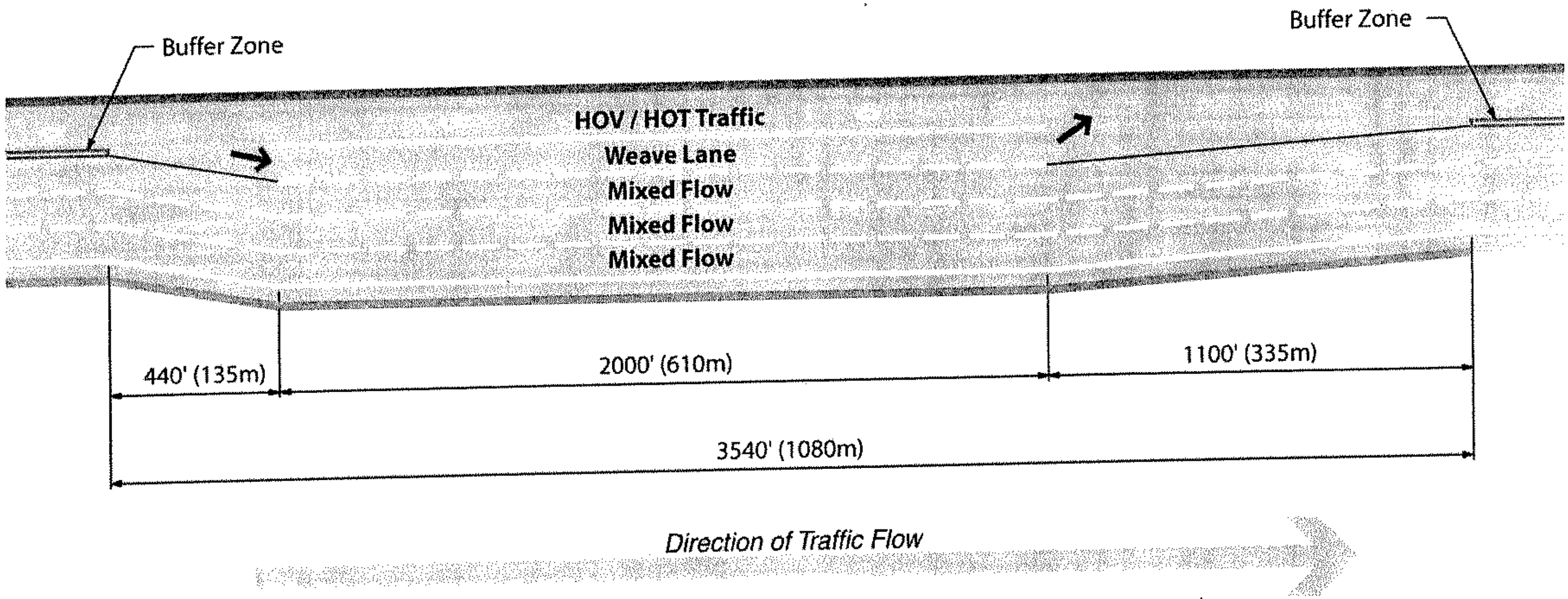


Figure 4-7

Application of Access to I-680 Corridor

The initial traffic investigation on this corridor indicates that the majority of HOV/HOT users along I-680 corridor from Route 84 to Route 237 travel the entire corridor, especially during the peak periods. However, within these limits, there are a total of 12 interchanges with an average spacing of little more than one mile. It appears that a limited access system is possible for the corridor, but at least one intermediate access location should be considered to accommodate those potential users who do not need to travel the entire HOV/HOT corridor.

For the purposes of this study, Route 262/Mission Boulevard was identified as a favorable location, because it links parallel and heavily-used I-680 and I-880 corridors. Furthermore, Route 262/I-880 improvements planned for completion in 2008 will likely increase the demand from and to Route 262. Intermediate accesses are generally designed and located at a segment between two adjacent interchanges (also Figure 4-7). This intermediate access geometry provides egress/ingress transitions and an additional lane for weaving operations for traffic existing and entering the HOV/HOT lane. The locations of the egress/ingress within the two adjacent interchanges should take into account the volume of weaving and the distance required to the merge points at entrance ramps and the diverge points at exit ramps.

In this case, a full intermediate access is proposed <u>both to and from Route 262</u>. This includes egress to the southbound off-ramp to Route 262 and ingress from the Route 262 southbound on-ramp, requiring construction of two separate access locations. The locations of the ingress/egress are set at 2,000 feet from the exit and entrance ramps to allow for weaving operations. The final locations will be adjusted based on the actual volumes and operational analysis. The cost for the southbound improvements with full access to Route 262 is estimated at $2.3 million. A similar improvement for the northbound I-680 access to Route 262 would be required, also estimated at $2.3 million. Thus, the total additional cost for the intermediate access would be $4.6 million. This cost is included in Table 4-2 above in the cost summary for Alternative A-4.

<u>Other HOV/HOT Improvements</u>
The operational analysis (see Chapter 9) indicates that additional mixed flow lanes for mitigating merging and weaving operations at the termination of HOV lanes are required, whether or not a HOT lane is implemented. The proposed improvements are: (1) addition of a weaving lane in the southbound direction between the off/on ramps at Scott Creek Road and Jacklin Road Interchanges, and addition of a weaving lane in the northbound direction between the off/on ramps at Route 238 and from the off-ramp to Truck Scale to Route 84 (discussed and depicted in Chapter 9).

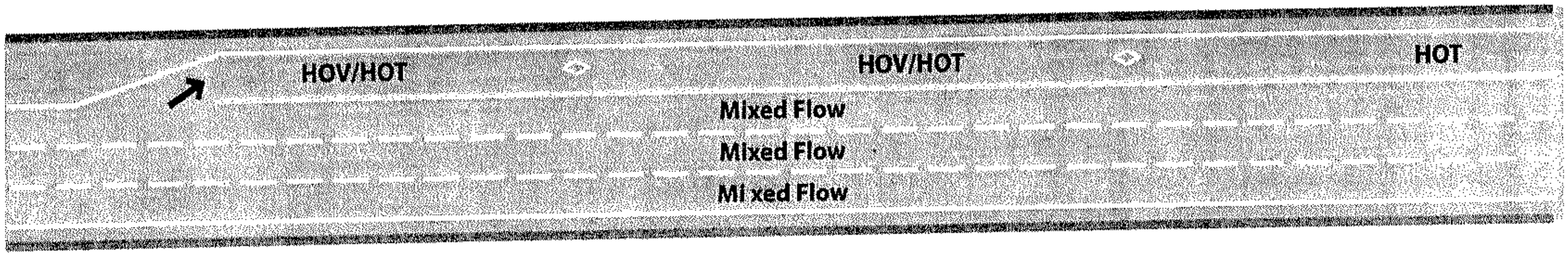
<u>Entrance Options to the HOV and HOT Lanes</u>
There are two possible transition/entrance geometric options to the HOV/HOT lane, which are shown in Figure 4-8:

(1) A combined single lane entrance for both HOV and HOT lanes. This is a conventional geometry and it is similar to the nearly all of the HOV lane entrances throughout California. Under this option, the California Highway Patrol would be able to enforce the lane both visually and (in the case of HOT lanes) electronically at these locations.

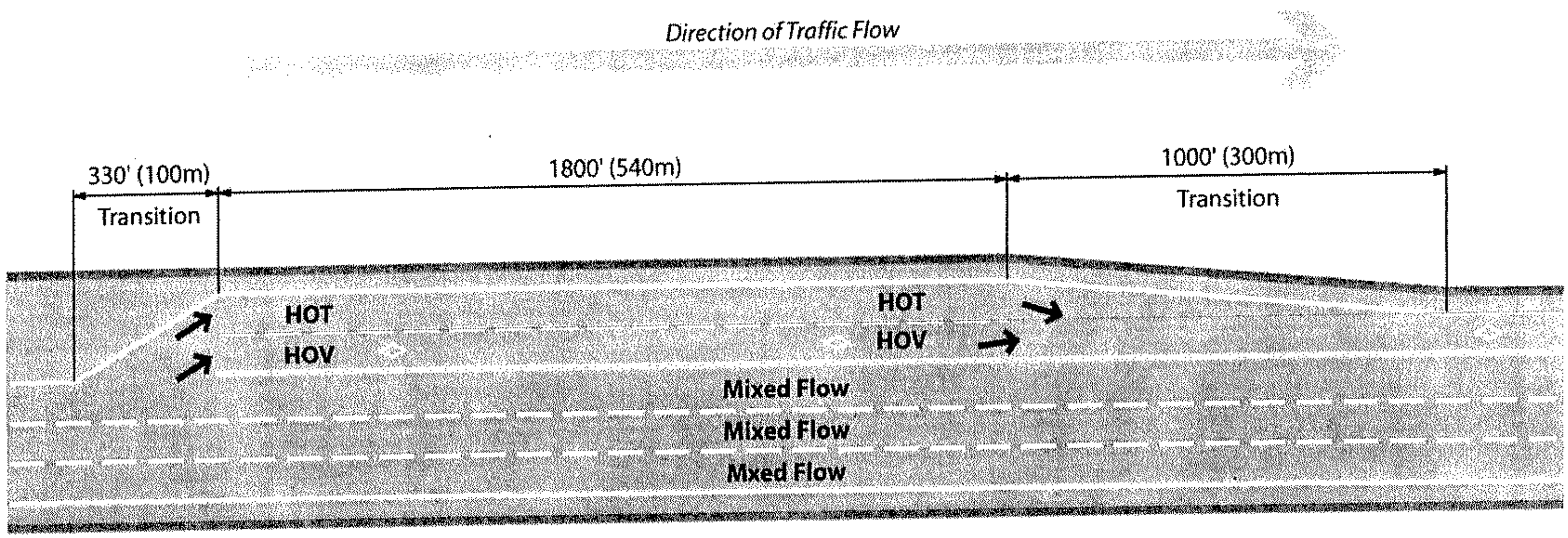
(2) An additional transition and a single lane entrance for the HOT lane in the vicinity of the Route 262/Mission Boulevard interchange. After the HOT entrance, the additional lane would taper and transition back to the HOV lane. CHP would be able to enforce the lanes visually and electronically; however, this option appears to be designed for the visual inspection of the HOT users where no electronic inspections are provided. With this option I-680 would require additional freeway widening at its north and south entrances and two at the intermediate access. The cost for these additional freeway widenings are estimated at $5.7 million.

Because any recommended I-680 HOT system is likely to include electronic/video monitoring and detection at its entrances and periodically throughout its length, an additional HOT lane entrance may not be necessary for this corridor and is not recommended. The final decision for which option to employ would be determined by the type of electronic inspection and consultation with the CHP.

HOV/HOT Entry Options



OPTION 1



OPTION 2

Figure 4-8

Interim HOV/HOT Lane Alternatives

An analysis of "interim" HOV/HOT lane alternatives with physical barriers was conducted, in order to keep open the possibility of early deployment. The following options were considered.

Interim Alternative 1 – Moveable Barrier

Under this alternative, the proposed southbound HOV lane will be used as an AM southbound peak hours HOV lane, and a contra-flow northbound HOV lane in the PM peak hours. A moveable barrier will separate the mixed flow lanes and the contra flow lane. The moveable barrier will sit next to the fixed median barrier during the AM peak hours. Under this alternative HOV access to all interchanges will be provided during the AM peak hours and no access will be provided during the northbound HOV contra-flow, PM hours. Design exceptions will be required for lane and shoulder widths for the interim period. Table 4-2 shows the preliminary construction cost estimate for this alternative, not including toll collection costs (discussed for all options in Chapter 5):

Table 4-2: Interim Moveable Barrier

Item	**Capital Cost (millions $)**	**Operating Cost/Yr (millions $)**
Moveable Barrier, 22.4 Km @ $0.75M/Km	$16.8	
Transfer Machine, 1 @ $0.9M Each	$0.9	
Maintenance @ $0.75M		$0.75
Garage/Maintenance Center	$1.0	
Miscellaneous Civil Work	$2.0	
Total	**$20.7**	**$0.75**

Interim Alternative 2 – Temporary Barrier

Under this alternative, temporary railing will be installed to separate the HOV lane from the mixed-flow lanes to both serve HOV traffic traveling south in the AM peak hours and traveling north in the PM peak hours. Design exceptions are similar to those in Interim Alternative 1. At the end of the interim period, the temporary barriers will be removed and the freeway will return to its original section. This alternative has two options, either one intermediate access at Route 262 (Mission Boulevard) or no intermediate access. Under this option the temporary barrier will not be installed within the access area, and moveable barriers will be used to separate the contra-flow lanes in the PM peak hours. No intermediate access will be provided in the contra flow lanes in the PM peak hours. Table 4-3 shows the preliminary construction cost estimate for this alternative:

Table 4-3: Interim Temporary Barrier

Item	Capital Cost (millions $)	Operating Cost/Yr (millions $)
Temporary Barrier, 22,400 m @ $50/m (Install)	$1.12	
Temporary Barrier, 22,400 m @ $20/m (Remove)	$0.448	
Miscellaneous Civil Work	$2.0	
Moveable Barrier, 1.2 Km @ $0.75M/Km (two ends of project)	$1.5	
Transfer Machine, 1 @ $0.9M Each	$0.9	
Maintenance @ $0.75M		$0.75
Garage/Maintenance Center	$1.0	
Total Cost (no intermediate access)	**$6.968**	**$0.75**
Ingress/egress improvements (intermediate access only)	$2.3*	
Moveable Barrier, 2.2 Km @ $0.75M/Km (intermediate access only)	$1.65*	
Total Cost (with intermediate access)	**$10.918**	**$0.75**

*For intermediate access, add this capital cost to the total cost.

Pilot Project in Southbound Direction

Another interim option would be to adopt the HOT lane concept as a pilot or demonstration project in only the southbound direction, because the southbound HOV lane will be brought up to Caltrans standard before the northbound HOV lane is constructed. A pilot project would provide the opportunity to test the financial and operational forecasts and to adjust the HOT lane based on actual experience. A request for a federal earmark for funding the pilot project may be made through local members of Congress.

The costs of a three-year pilot project for a southbound HOT lane would include:

(1) Weaving lane for intermediate access (if that option is selected) of approximately $2.3 million;
(2) Toll collection/enforcement capital and operations cost, which will be somewhat more than half of the $3.24 million capital and $1.02 million annual operating costs estimated for the full bi-directional project estimated in Chapter 5. The reason for a disproportionate one-direction cost is that nearly the same "systems" elements (e.g., such as software, telecommunications, administration, etc.) must be in place whether the HOT lane is one or two directions;
(3) Substantial monitoring and evaluation, so that lessons learned can be applied to I-680 and other similar corridors around the state and nation.

A pilot project southbound would provide several important advantages. First, it could be implemented much more quickly (as early as 2006) than the full bi-directional project. Second, it could begin yielding income that could help fund northbound improvements, I-680 corridor transit service, or other transportation purposes. Finally, the eventual full implementation of bi-directional HOT lanes would benefit from valuable experience in how to operate a HOT lane successfully in this and similar corridors.

CHAPTER 5:
TOLL COLLECTION OPTIONS AND COSTS

This chapter discusses and provides cost estimates of alternatives for toll collection to for I-680 HOT lanes. It includes estimates for HOV/HOT configurations with and without intermediate access.

Alternative Technologies

There are two primary toll collection approaches that have been used to allow SOVs to use HOT lanes:

1. A system employing a simple placard or decal, affixed visibly on the vehicle, indicating eligibility to use the HOT lane
2. An electronic toll collection (ETC) system

1. Placard System

The simplest approach to implement for controlling SOV usage of the HOV is a placard or decal program, consisting of a pass visibly affixed to the vehicle, issued on a periodic (most likely monthly or quarterly) basis in exchange for paying a fee. It is displayed to authorize a non-eligible vehicle (i.e., not an HOV) to use the HOV lanes during the hours that are otherwise restricted for HOV-only usage. The placard/decal needs to be large enough to be easily spotted by the California Highway Patrol (CHP) for enforcement and mounted on a uniform location on all vehicles.

The only way to control the number of fee-paying authorized vehicles is by limiting the number of passes that are distributed. The CHP can provide enforcement by ticketing all non-authorized vehicles for violation of the HOV lanes. Freeway management data detailing the HOV and HOT vehicle counts must be collected manually by observing the traffic. It is entirely possible that the number of passes issued would have to be adjusted periodically, depending upon the traffic flow and the degree of usage of the HOV lane by SOVs with paid permits. This approach does not charge a per trip fee, nor does it not allow for variable pricing based on traffic conditions or time of day.

2. Electronic Toll Collection

Electronic Toll Collection (ETC) systems are available from several manufacturers and vary greatly in cost and functionality. For HOT lane applications the systems are typically comprised of an overhead antenna/reader mounted on a gantry or an overpass, an in-vehicle transponder, a central computer system to collect data and process the charges of lane usage, and fiber-optic lines linking the elements together. The antenna automatically reads the transponder and deducts the toll amount from a prepaid account. The account is typically replenished automatically by linking it to a credit card or bank account.

This system is already in effect for San Francisco Bay Area bridges in the form of the Fastrak electronic toll collection system. Some systems, including those at the bridges, include video cameras as part of a violation enforcement system. The standard on the West Coast for interoperable electronic toll collection equipment is Title 21 transponders. Any toll system on the I-680 corridor would use transponders that were valid and compatible with the region's bridges as well. The accounting and remittance of revenues to potential different operators would follow a similar method to that used to distinguish the Golden Gate Bridge from the Bay Area's state-owned toll bridges.

ETC charges on a per-trip basis, allows for variable pricing by time of day and can collect tolls for use of one or more segments of an HOT lane. It also provides the benefit of easy collection of data about usage.

HOV/HOT Enforcement

The permit system relies exclusively on police visual enforcement. ETC generally involves some combination of police enforcement and electronic surveillance. Two factors facilitate effective enforcement: (1) physical barrier separation between HOV/HOT lanes and mixed-flow lanes and (2) few, if any, intermediate access points into and out of the HOV/HOT lanes. Physical barrier separation and limited access allow less opportunity for violators to evade paying the toll, and also reduce the need for multiple overhead electronic toll readers along the corridor.

A buffer consisting of striping and/or plastic pylons to indicate authorized ingress/egress locations for HOVHOT lanes is obviously less effective for enforcement than a concrete physical barrier would be. However, the toll collection and enforcement effectiveness of a buffer system can be improved greatly by a combination of: (1) visible signal to register whether a toll has been paid (e.g., overhead light on the reader that flashes when a vehicle passes under); (2) multiple toll readers along the corridor, so that even if a vehicle does not pay a toll at the entrance, another reader down the corridor will "catch" the vehicle and charge a toll; (3) video surveillance and monitoring to deter or detect those who violate either the toll payment or those entering or leaving the lane at an unauthorized location; and (4) additional CHP enforcement presence. A system incorporating these features is depicted in Figure 5-1 on page 40.

Toll Collection Option 1: Placard System (no ETC)
This option relies upon visual enforcement by the highway patrol. It is relatively inexpensive to initiate and administer. Because it does not entail a per-trip fee, it does not encourage permit-holders to limit their usage to high value trips and therefore may not provide nearly as much freeway management capability as would a system charging on a per-trip basis. In San Diego's I-15 HOT lanes, the placard system was used for the first phase of the project but replaced by electronic toll collection within one year.

Table 5-1: Placard System Cost-Option 1

Equipment	Quantity	Unit Cost $	Capital Cost $	Annual Operating Cost $
Placards/decals	1,000/mos	10		120,000
Engineering/ Design	1	575,000	575,000	
Administration	Per year	150,000		150,000
Violation Enforcement – Enhanced CHP presence	Per year	200,000		240,000
TOTAL			**$575,000**	**$510,000**

Toll Collection Option 2: ETC, 1 lane in each direction, no intermediate access

This option utilizes electronic toll collection equipment to permit single occupancy vehicles to have access to the HOV lane. A radio-frequency antenna/reader site will be installed near the beginning of each lane and an additional intermediate antenna/reader will be installed to increase system reliability and discourage violations. This option provides for one lane in each direction with no intermediate access.

Table 5-2: ETC Cost- Option 2

Equipment	Quantity	Unit Cost $	Capital Cost $	Annual Operating Cost $
Antenna/Reader	4	18,000	72,000	
Transponders	15,000	35	525,000	
Central Computer System hardware	1	65,000	65,000	
Central Computer System software	1	110,000	110,000	
Communication to VMS Dial-up phone lines	2	1,000	2,000	1,000
Communication to Antenna/ Readers T-1 phone up lines	4	1,000	4,000	24,000
Redundant communications/power	1	75,000	75,000	
Antenna mounting gantry (others mount on existing signs/ poles)	2	55,000	110,000	
Variable Message Sign	2	55,000	110,000	
VMS pedestal/ installation	2	110,000	220,000	
Installation of antennas, readers, central computer	1	220,000	220,000	
Violation enforcement -CHP	Per year	240,000		240,000
System Design/ Development	1	700,000	700,000	
Training	Per year		40,000	
Maintenance	Per year	110,000		90,000
Oversight & reporting	Per year	75,000		75,000
Administration/marketing	Per year	405,000		405,000
TOTAL	-	-	**2,253,000**	**835,000**

Toll Collection Option 3: ETC, 1 lane in each direction, 1 intermediate access, 4 additional readers, video surveillance

This option utilizes electronic toll collection equipment to permit access of single occupancy vehicles to the HOV lane. Antenna sites will be installed near the beginning of each HOT lane and at one intermediate access area in each direction. Additional antennas will be installed several miles past the initial and intermediate access point antennas to increase reliability (redundancy in case the first reader is not operating) and to discourage violations, for a total of eight readers. This option also includes robust video surveillance. This option represents a high level of toll collection and enforcement.

Table 5-3: ETC Cost-Option 3

Equipment	Quantity	Unit Cost $	Capital Cost $	Annual Operating Cost $
Antenna/ Reader	8	18,000	144,000	
Transponders	15,000	35	525,000	
Central Computer System hardware	1	65,000	65,000	
Central Computer System software	1	110,000	110,000	
Communication to VMS Dial-up phone lines	4	1,000	4,000	3,000
Communication to Antenna/ Readers T-1 phone up lines	8	2,000	16,000	35,000
Redundant communications/power	1	75,000	75,000	
Closed-circuit TV (CCTV) cameras	12	6,000	72,000	
CCTV mounting	12	15,000	180,000	
CCTV recording equipment	1	30,000	30,000	
Antenna mounting gantry (others mount on existing signs/ poles)	4*	55,000	220,000	
Variable Message Sign	4	55,000	220,000	
VMS pedestal/ installation	4	110,000	440,000	
Installation of antennas, readers, central computer	1	440,000	440,000	
Violation enforcement - CHP	Per year	240,000		240,000
System Design/ Development	1	700,000	700,000	
Training	Per year	40,000		40,000
Maintenance	Per year	220,000		220,000
Oversight & reporting	Per year	75,000		75,000
Administration/marketing	Per year	405,000		405,000
TOTAL	-	-	**3,241,000**	**1,018,000**

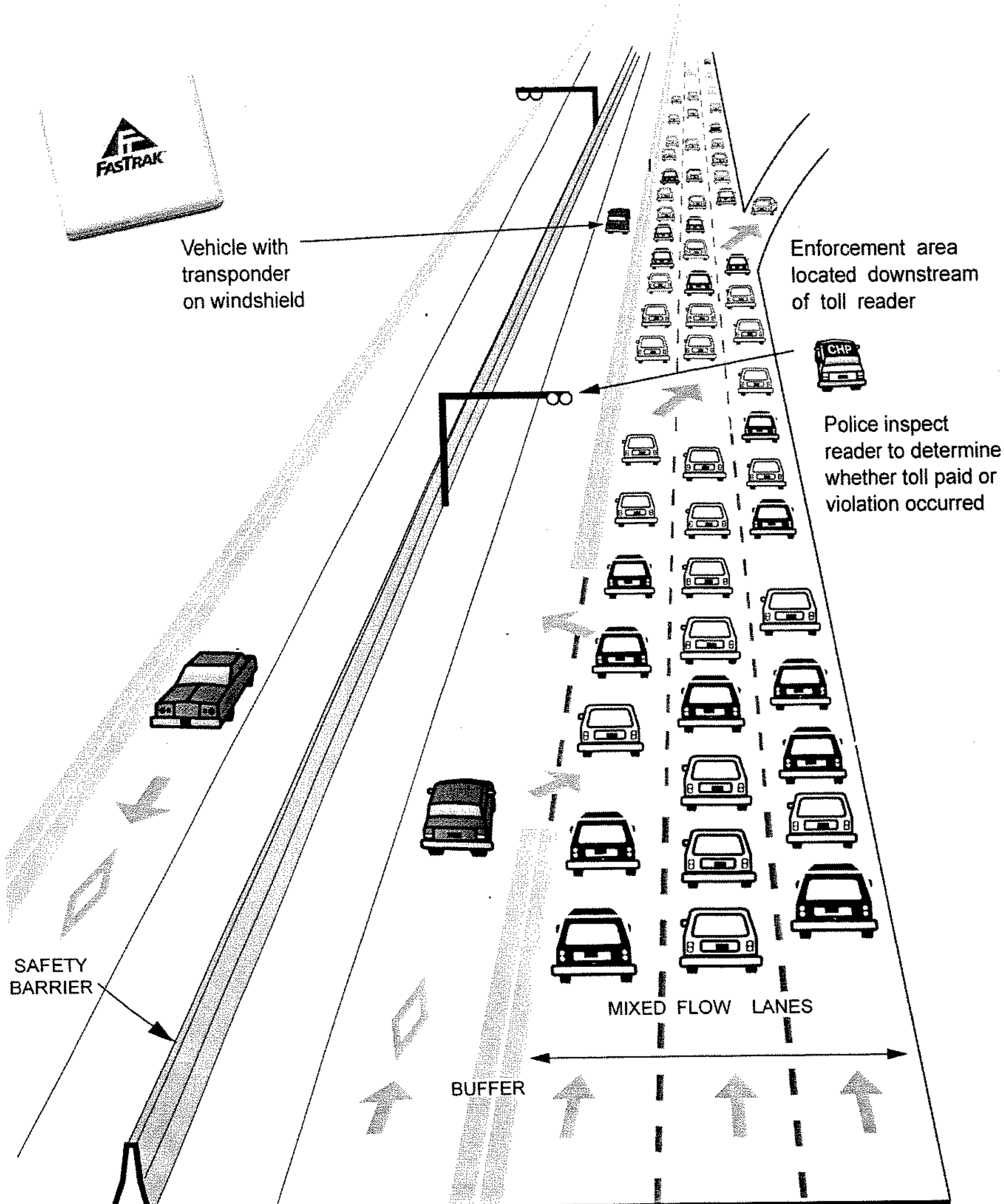
* Assumes that additional readers in each direction will be mounted on existing structures.

Toll Collection Option 4: ETC, 2 reversible lanes, 1 intermediate access, 4 additional readers, video surveillance

Option 4 has both lanes serving HOV/HOT in southbound direction for AM peak, and northbound direction for the PM peak. This design includes one intermediate access point to the HOV/HOT lanes. As in Option 3 above, additional antennas will be installed several miles past the initial and intermediate access point antennas to increase reliability (redundancy in case the first reader is not operating) and discourage violations, for a total of eight readers. This option also includes robust video surveillance. This option represents a high level of toll collection and enforcement.

Table 5-4: ETC Cost-Option 4

Equipment	Quantity	Unit Cost $	Capital Cost $	Annual Operating Cost $
Antenna/Reader	8	18,000	144,000	
Transponders	15,000	35	525,000	
Central Computer System hardware	1	65,000	65,000	
Central Computer System software	1	110,000	110,000	
Communication to VMS Dial-up phone lines	4	1,000	4,000	2,000
Communication to Antenna/ Readers T-1 phone up lines	8	2,000	16,000	35,000
Redundant communications/power	1	75,000	75,000	
Closed-circuit TV (CCTV) cameras	8	6,000	48,000	
CCTV mounting	8	15,000	120,000	
CCTV recording equipment	1	30,000	30,000	
Antenna mounting gantry (others mount on existing signs/ poles)	4	55,000	220,000	
Variable Message Sign	4	55,000	220,000	
VMS pedestal/ installation	4	110,000	440,000	
Barrier Gates	2	3,000	6,000	
Controller for Gates	1	75,000	75,000	
Installation of antennas, readers, central computer	1	180,000	180,000	
Violation enforcement - CHP	Per year	200,000		240,000
System Design/ Development	1	700,000	700,000	
Training	1	40,000		40,000
Maintenance	Per year	125,000		125,000
Oversight & reporting	Per year	75,000		75,000
Administration/marketing	Per year	405,000		405,000
TOTAL	-	-	**2,978,000**	**922,000**



Source: Parsons Brinckerhoff, 2003

Figure 5-1
Typical Enforcement Configuration HOT Lanes: Striped Lane Separation, Electronic Toll Collection with Enhanced Highway Patrol

CHAPTER 6:
EVALUATION CRITERIA

The following set of criteria is used in evaluating the alternatives and the overall feasibility for variable pricing or HOT lanes in conjunction with the planned HOV lanes widening on Interstate I-680. The objective is to compare the various HOT lane alternatives with the HOV lane configuration planned by Caltrans.

1. Corridor Travel Impacts.
This criterion considers person-throughput, travel time and delay impact to users of the HOV/HOT lanes and overall freeway users. It can be measured by aggregate person-miles-traveled, average travel times and total delay impacts for all corridor users.

2. Operational Impacts
This criterion measures impacts to general traffic in the mixed-flow lanes, impact on HOVs in the HOV lanes, and at the interchanges. There is particular focus on potential bottlenecks attributable to configuration decisions, such as the number and location of access to the HOV/HOT lanes.

3. Geometric Impacts
This criterion assesses compatibility with Caltrans and national design standards, including any impacts on roadway geometry, overcrossings, and other design features.

4. Safety
This criterion examines the potential change for accident rates, due to different roadway configurations and weaving characteristics, and based on engineering judgment of the geometric and operational aspects of each alternative.

5. Tolling and Enforcement Feasibility
This criterion assesses the feasibility of effective toll enforcement along with the HOV lane occupancy enforcement that will be in place for conventional HOV lanes. It will consider the impact of applying technology options and enhanced enforcement levels.

6. Travel Options Enhancement
This criterion evaluates whether the alternatives enhance or detract from traveler options in the corridor. This will investigate what travel options each alternative provides or takes away, compared among the alternatives and with the base case. Variables could include number and location of access points and eligibility of different vehicles.

7. Capital Cost
This criterion measures the incremental cost of implementing HOT lanes, above the cost of conventional HOV lanes. This will include the cost of any physical changes to the roadway, structures or right-of-way, toll reading equipment, signage and other "upfront" costs associated with implementing a pricing component on a highway with HOV lanes.

8. Revenue Generation
This criterion evaluates the gross projected revenues to be generated by allowing toll-payers to use the HOT lanes. It assesses the magnitude of the potential market.

9. Net Operational Cost/Revenue
This is the most important financial criterion. It measures the incremental cost, including maintenance, administration and marketing, to operate the lanes and then compares the cost with revenue collected, yielding the net operational cost or revenue.

10. Environmental Impact
This criterion reviews any significant impacts on the environment. This will be a general qualitative review searching for any clear significant impacts or fatal flaws, not a comprehensive environmental report.

11. Equity Impact
This criterion examines distribution of benefits and detriments to different populations, focusing on the question of who benefits and who pays.

12. Transit Impact
This criterion assesses impact on existing and proposed public transit in the corridor. Evaluation will include potential impact on express bus and rail service, including effect on performance of the HOV lanes and potential for HOT lane revenues to fund additional transit service.

Applying the Evaluation Criteria

These criteria can be characterized in different terms; some are quantitative, others qualitative; some are about significant or insignificant impacts; and some are about ease or difficulty of implementation. Because a conventional HOV-only lane is effectively the "base case" of this comparison, each of the HOT lanes will be compared to HOV-only scenario.

In Chapter 12 of this report (Evaluating the Alternatives) each alternative is given a rating on each criterion. Furthermore, a narrative description of the pros and cons of each alternative is provided. Because the determination of "feasibility" is a public policy decision that weighs different, and often competing, values against one another, no attempt is made by the study team to weight the criteria or develop a comprehensive score for each alternative.

Corridor travel and operational impacts are found in Chapter 9 (Operational Analysis) of this report. Capital costs are found in Chapter 4 (Alternatives) and Chapter 8 (Revenues and Financial Feasibility). Financial data on revenues and operational costs are found in Chapter 8 and Chapter 5 (Toll Collection Options). A discussion of equity impacts is found in Chapter 11 (Policy Considerations).

CHAPTER 7
TRAVEL FORECASTING

This chapter discusses the travel demand modeling approach used in the I-680 Value Pricing Study. In addition to the information presented in this report, a series of Technical Memoranda are available, and referenced here, which provide a detailed account of various aspects of the travel demand forecasting methodology and results.

The goal of the demand modeling portion of the study is to facilitate the forecasting of various capacity additions to I-680 in the Sunol Grade corridor, namely High Occupancy Vehicle (HOV) and High Occupancy Toll (HOT) lanes. The modeling explicitly recognizes the choice travelers make in choosing to travel in carpools or in toll lanes. The end result of the travel demand model was used as input for the Toll Optimization Model (Chapter 8) and the simulation modeling for the Operational Analysis (Chapter 9).

Modeling Approach

The primary modeling tool used in the I-680 Value Pricing Study is the Metropolitan Transportation Commission's (MTC) BAYCAST travel demand model set. The MTC model was enhanced in 2001 by the Santa Clara Valley Transportation Authority (VTA), who improved the functionality of the BAYCAST mode choice model and also performed a year 2000 validation. All the modeling work for the I-680 Study pivots off the model developed by the VTA. This model was also used in the Caltrans environmental document for the I-680 HOV lane.

The focus of the I-680 Value Pricing Study is to formally estimate the demand for a parallel HOT facility in the I-680 corridor. The existing MTC/VTA model did not have the ability to explicitly model the choice between traveling on a general purpose facility with mixed-flow lanes and a time-savings value toll facility (HOT lane). The goal of this effort was to overcome this shortcoming. Please note: the term "toll" in the remainder of this document will refer to "value tolls" – a toll paid solely to provide a time savings. This is contrast to a "bridge toll," which is common in the Bay Area, paid to cross a natural obstruction which is otherwise impassable – in this case the Bay.

The approach taken in the I-680 Study was to include the Toll/No Toll choice in the existing MTC/VTA Mode Choice models. This was accomplished by adding sub-nests under each of the primary auto modes (Drive Alone, Shared Ride 2, Shared Ride 3+) in the existing Nested Logit models. Figure 7-1, below, generically depicts this addition.

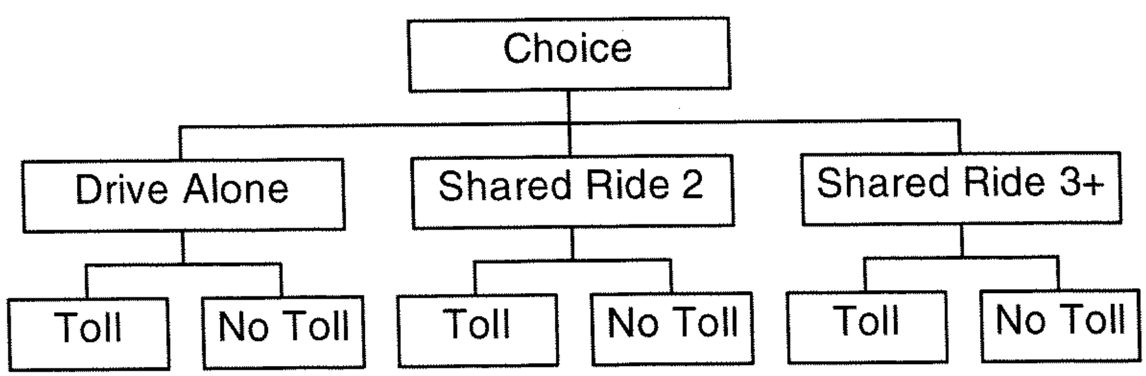


Figure 7-1: Generic Representation of Toll/No Toll Nesting Structure

As each of the MTC/VTA Mode Choice models (segmented by Trip Purpose) differ, the modifications to the nesting structures varied from Trip Purpose to Trip Purpose. For a complete discussion of the modifications made to the Mode Choice models, please refer to Appendix B, the technical memorandum *I-680 Value Pricing Study: Travel Demand Modeling Program and Mode Choice Specifications*[5].

Toll Model Testing

After modifying the mode choice structure, a rigorous validation process was followed to ensure the enhanced model stream was capable of representing existing conditions. Because the San Francisco Bay Area currently has no "value pricing," or variable priced, toll facilities, the validation provided no information as to the performance of the model when faced with the introduction of a toll facility. For this reason, a formal testing of the model stream was performed.

The testing procedure involved coding a toll facility on the VTA's 2025 RTP highway network in the I-680 corridor of interest. A toll facility consisted of a 14-mile long, single-lane facility with a single access and single egress point, which ran parallel to I-680 from Route 84 in the north and Calaveras Boulevard in the south. Different toll fees were then introduced for the facility and various performance measures were computed, including toll elasticity by trip purpose. For a complete discussion of the toll testing procedures and results, please refer to Appendix C, *I-680 Value Pricing Study: Travel Demand Modeling Toll Testing Results*[6].

After successfully testing the I-680 Model for both the base year of 2000 and the horizon year of 2025, the model was ready to test alternatives.

Use of Model Results

The demand modeling results for the alternatives are included in Appendix D, *Travel Demand Modeling Methodology and Alternatives Analysis*. The benefit of the modeling process in this study was to provide detailed input for the Toll Optimization Modeling and the Operational Analysis.

As elaborated upon in Chapter 8, the purpose of the Toll Optimization Modeling is to determine what share of travelers in the I-680 corridor will choose to use the High Occupancy Toll (HOT) facility at a given price. The travel demand modeling provided the Toll Optimization Model with the population of travelers in single occupancy, high occupancy, and toll-paying vehicles in the corridor during the peak hours. The demand model and Toll Optimization Models were then used in an iterative fashion to determine the optimal toll.

Once the toll users were segmented using the Toll Optimization Model, the volumes were then used as input in the Operational Analysis simulation model, as discussed in Chapter 9. The Operational Analysis is capable of producing a detailed description of the congestion levels in each alternative. The demand model provided the input for the future year conditions.

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5 *I-680 Value Pricing Study: Travel Demand Modeling Program and Mode Choice Specifications*, Technical Memorandum prepared by Parsons Brinckerhoff for the Alameda Congestion Management Authority and California Department of Transportation, April, 2002.

6 *I-680 Value Pricing Study: Travel Demand Modeling Toll Testing Results*, Technical Memorandum prepared by Parsons Brinckerhoff for the Alameda Congestion Management Authority and California Department of Transportation, August, 2002.

CHAPTER 8:
REVENUES AND FINANCIAL FEASIBILITY

This chapter discusses the determination of optimal tolls, revenue generation, and financial feasibility for the I-680 HOT lane alternatives. The analysis was done on Alternative A-3 (striped buffer, no intermediate access) and Alternative A-4 (striped buffer, one intermediate access). Both Alternatives were modeled for years 2000 and 2025 under two distinct carpool policies: (1) two or more persons defined as a high-occupancy vehicles (denoted as "2+") and eligible to use the HOV lane without paying a toll; (3) three or more defined as a high-occupancy vehicle (denoted as "3+"). The results from the toll modeling enabled projection of tolls, traffic volumes, speeds, and revenue under optimal tolling for all alternatives, including both access configurations and both carpooling policies in 2000 and 2025.

Assumptions of the Toll Analysis

The toll optimization analysis assumes that the goal of the tolling strategy is to maintain acceptable traffic performance of the HOV/HOT lanes and operate the facility in an efficient manner. Efficiency in the sense used here means minimization of the total delay, in terms of value of time of all users on the facility, i.e., HOV/HOT lane and mixed-flow lane users, at the total traffic volume forecast for the facility. In addition, equity considerations are implicit in policies imposed on the operation of the project, such as the provision of free access to the HOT lane for vehicles with two or three or more users (HOV 2+ and HOV 3+, respectively). The optimization process seeks the most efficient tolls, given these operational policies.

The analysis of optimal toll levels is conducted under a "variable rate" pricing structure for Alternative A-4, which unlike Alternative A-3, has a second, intermediate set of HOT lane entrance and exit points in each direction. This structure differentiates toll levels by the time of day and day of week, and by road segment and direction. For Alternative A-3, with no intermediate access and therefore only one tolling segment (the entire 14-mile length of the facility) in each direction, the tolls vary only by time of day and direction.

For the purpose of this analysis, the pricing structure is simplified in the sense that we employ only five different levels or *classes* of tolls (denoted, from highest rate to lowest, as A, B, C, D, and E) in each direction across the various times of day during weekdays and the weekend. In addition, tolls are charged on a per vehicle basis, with no differentiation among classes of vehicles eligible to use the lane (including passenger vehicles, SUVs and light trucks), since no heavy trucks are to be permitted in the lane.

The use of a simplified pattern of toll levels recognizes that drivers may be confused by a structure that has many more toll levels. Moreover, although traffic varies across times of day, days of the week, and direction, the price of tolls drops significantly outside of peak hours, so revenue estimates and facility efficiency are little affected by limiting the number of toll classes. For example, within both the southbound AM peak period and the northbound PM peak period there are some differences in the volume of traffic per hour using the facility (the northbound PM peak is somewhat more spread out than the southbound AM peak). Similarly, shoulder and weekend and night tolls need to be different because of the very different levels of traffic observed during these times. These differences are accounted for in the different toll levels. Nevertheless, this relatively simplified analysis does not preclude eventual adoption of "dynamic" toll pricing (currently used in the San Diego I-15 HOT lanes), which allows the toll levels to change in real time to reflect actual highway conditions at any given time.

The Procedures Used for Optimizing Toll Levels

The process by which toll levels are optimized is as follows:

- Preliminary estimates of traffic volumes on both the tolled and untolled lanes are obtained from runs of the MTC model.[7]

- The AM peak data is used, along with information on current time-distributions of traffic on I-680 to develop first-pass traffic volume estimates for the other hours of the day, and for weekend hours.

- A customized, mathematical representation of the affected portion of the network is prepared that permits finer and more rapid optimized assignment of traffic on the network in response to pricing than is possible using the MTC model.[8] This mathematical representation (ECONorthwest's *Toll Optimization Model or TOM*) allows for calculation of optimal tolls.

- Toll levels and hourly traffic volumes for each toll class and for the adjacent untolled lanes are simultaneously determined by an optimization process that seeks to find tolls that meet the relevant efficiency criteria.

- If the TOM calculation results in a large change in AM peak volumes (from the initial MTC run level), the toll level for the AM peak period is used to recalibrate the MTC model run, and the optimization process is repeated.

As this description suggests, the optimization procedure works iteratively with the MTC model. The iteration between the MTC model and TOM is necessary because the current MTC model cannot mathematically handle the dual path choice and toll optimization problem in facilities with combinations of HOT and mixed-flow lanes and multiple vehicle classes. The reason is that the user's decision to select the HOT versus mixed-flow lanes depends upon the trade-off between paying tolls and travel time or speed faced by users with different values of time. Specifically, users face the choice of selecting the HOT lane (paying the toll and enjoying higher speeds), versus staying in the mixed-flow lanes (not paying the toll and suffering slower speeds). How many users make the decision to use the HOT lane depends crucially on the composition of time values of users in the traffic stream. This cannot be modeled within standard models or traffic assignment models and requires the use of TOM.

Accounting for Peak Spreading between 2000 and 2025

The MTC model is run for both the years 2000 and 2025. However, because the MTC model reports only the AM peak traffic volumes, the growth reported in these volumes is not representative of growth in average daily traffic (ADT), because the facility approached capacity during the AM peak in 2000. In fact, traffic will continue to grow between 2000 and 2025, but will be accommodated during periods outside of the current AM and PM peak periods. This phenomenon, known as peak spreading, can be observed over time as traffic grows. The TOM incorporates a mathematical method to replicate the peak spreading that likely will occur in a peak-constrained setting.

In this analysis, it is assumed that the overall volume of traffic will grow by 25 percent between 2000 and 2025.[9] This growth will occur in a manner described by the peak-spreading relationship. Figure 8-1

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[7] These estimates apply to both the northbound and southbound AM peak only. This is because the MTC model forecasts only the AM peaks; traffic volumes at other times of day must be obtained by applying a factor to the AM peak volumes. This was accomplished by using data on current daily traffic volumes for present-day estimates and using a peak-spreading algorithm for future years.

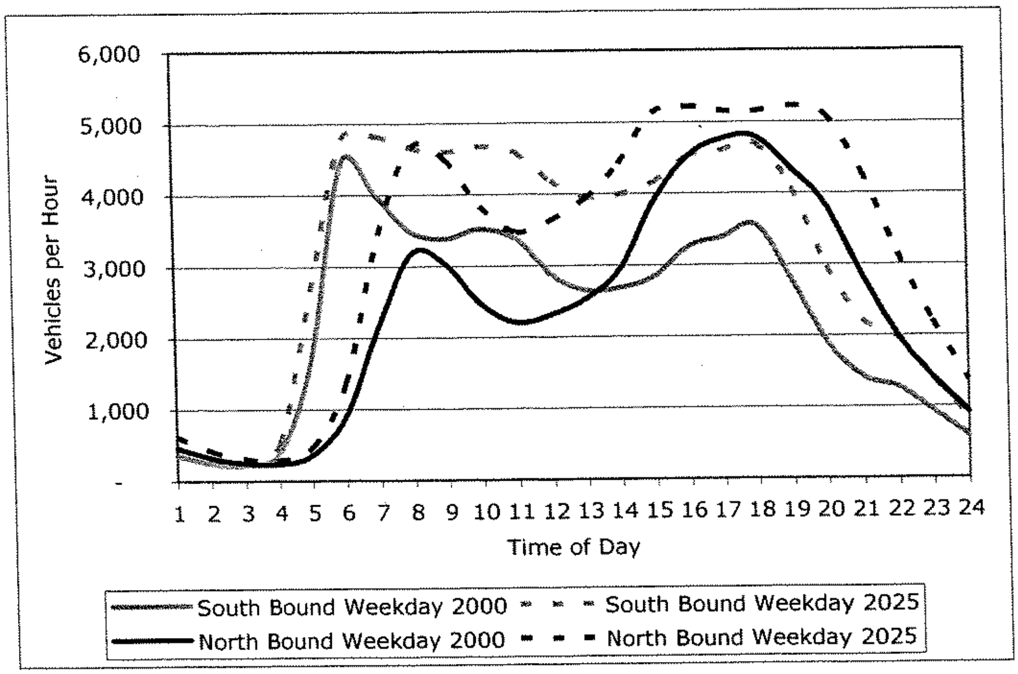
[8] Specifically, the ECONorthwest *Toll Optimizer Model* permits rapid calculation of tolls in a multiclass vehicle setting. The lengthy iterations and mathematical limitations of the MTC model make this optimization process impossible to conduct in that modeling context.

[9] This assumption was provided by ECONorthwest, in consultation with Parsons Brinckerhoff staff. To our knowledge, no 25-year ADT forecast is available for the corridor.

below illustrates the results of the peak-spreading exercise for the example of the weekday north and southbound directions.

The hourly volumes implicit in Figure 8-1 are used to seed the Toll Optimizer Model for the year 2025, for each of the five toll classes in each direction.[10] In so doing, it is possible to calculate the tolls and revenue for the five toll classes in 2000, as well as 2025.

Figure 8-1
Peak Spreading Relationship for the Weekday Northbound and Southbound Directions in 2000 and 2025



Determining Tolls at Different Levels of Congestion

The modeling process was completed for varying levels of congestion that correspond to different periods of the day, days of the week, and directions of travel. This step is needed in order to extrapolate the weekly and annual revenue potential of each alternative. Table 8-1 shows the periods modeled for Alternatives A-3 and A-4 in 2000. In general, the PM peak period is wider than the AM peak period. Consequently, more hours encompass the PM peak period toll class in the northbound direction, and fewer hours correspond to the off-peak toll class. Rate classes are designated A through E, A being the highest and E the lowest.

[10] In addition, adjusted weekend daily data was generated and incorporated into the tolling analysis.

Table 8-1: Periods used to assign Toll Classes in 2000

Rate Class	Typical Period to which Rate Class is Applied	Hours per Week
South Bound Rate A	AM Peak	10
South Bound Rate B	AM Shoulder/PM Peak	20
South Bound Rate C	PM Shoulder	20
South Bound Rate D	Weekend PM Peak	20
South Bound Rate E	Off Peak	98
North Bound Rate A	PM Peak	20
North Bound Rate B	PM Shoulder	20
North Bound Rate C	AM Shoulder	20
North Bound Rate D	Weekend PM Peak	20
North Bound Rate E	Off Peak	88

Determining Users' Value of Time

Most researchers suggest that travelers generally value their travel time at approximately 60 percent of their hourly wage. During this analysis, ECONorthwest relied on the average value of time estimates used in the MTC model, but used other information to estimate the variation of vehicle time values within each vehicle class (SOV, HOV2, and HOV3+). Table 8-2 shows the mean values of time for different vehicle classes assumed in the modeling. Vehicles' values of time are adjusted to 2002 dollars using an assumed 3% inflation rate.

Note that HOV2 and HOV3+ represent the value of time per vehicle-hour, and are adjusted to reflect the income quartile in the MTC model from which such travelers are drawn. The values for HOVs are higher than SOVs, because multiple persons' time is included. Income quartile data for the Bay Area are used to estimate the relative variance of travelers' value of time and thereby generate a distribution of time values around the average.

Table 8-2: Vehicle Values of Time per Vehicle-Hour by Vehicle Class

Vehicle Class	Average Value of Time Per Hour in 2002 Dollars
SOV/Small Trucks	$ 15.63
HOV2	$ 27.53
HOV3+	$ 41.30

Source: ECONorthwest from PB/MTC data

Optimized Toll Results

The types of data generated by the optimizing process are:

- Tolls, for the entire facility for Alternative A-3, and by segment for Alternative A-4
- Traffic volumes, by lane and link
- Speeds, by lane and link

Table 8-3 below summarizes the results of the toll optimization, for tolls charged to SOVs in Alternative A-3 under both an HOV 2+ and HOV 3+ carpool policy in both the northbound and southbound directions. The toll results for the years 2000 and 2025 are used to extrapolate toll levels in 2002 and 2006. The year 2006 is selected for analysis, because it is the earliest reasonable date to expect a HOT lane facility to begin service. Note that the peak period in the peak direction refers to rate class A.

Table 8-3: Peak-Period Toll Estimates for SOVs for Alternative A-3 in 2002, 2006, and 2025 Under HOV 2+ and HOV 3+ Carpool Policies

	Alternative A-3 HOV 2+	Alternative A-3 HOV 3+
Tolls in 2002 in 2002 Dollars		
PM Peak Toll in Peak Direction (NB)	$ 4.23	$ 5.02
PM Peak Toll in Peak Direction (NB) per Mile	$ 0.30	$ 0.36
AM Peak Toll in Peak Direction (SB)	$ 2.84	$ 3.73
AM Peak Toll in Peak Direction (SB) per Mile	$ 0.20	$ 0.27
Average Toll (both directions, all times of day)	$ 0.59	$ 0.72
Average Toll per Mile (both directions, all times of day)	$ 0.04	$ 0.05
Tolls in 2006 in 2002 Dollars		
PM Peak Toll in Peak Direction (NB)	$ 4.62	$ 5.23
PM Peak Toll in Peak Direction (NB) per Mile	$ 0.33	$ 0.37
AM Peak Toll in Peak Direction (SB)	$ 3.13	$ 4.04
AM Peak Toll in Peak Direction (SB) per Mile	$ 0.22	$ 0.29
Average Toll (both directions, all times of day)	$ 0.70	$ 0.83
Average Toll per Mile (both directions, all times of day)	$ 0.05	$ 0.05
Tolls in 2025 in 2002 Dollars		
PM Peak Toll in Peak Direction (NB)	$ 6.99	$ 6.34
PM Peak Toll in Peak Direction (NB) per Mile	$ 0.50	$ 0.42
AM Peak Toll in Peak Direction (SB)	$ 5.01	$ 5.97
AM Peak Toll in Peak Direction (SB) per Mile	$ 0.36	$ 0.43
Average Toll (both directions, all times of day)	$ 1.56	$ 1.62
Average Toll per Mile (both directions, all times of day)	$ 0.11	$ 0.12

Note: Peak toll refers to rate class A.
Source: ECONorthwest from PB/MTC data

The average tolls shown in the table above are derived by taking the average toll charged across rate period and directions, weighted by number of hours in each toll period.[11]

It is interesting to note that the highest per-mile tolls projected for 2002 and 2006 are 36 and 37 cents per mile; for 2025 the highest per-mile is 50 cents per mile. These tolls are considerably lower than the peak-period tolls currently being paid by users of SR 91 and I-15 in Southern California. Both SR 91 and I-15 roadways are comparable to Alternative A-3, in the sense they have no intermediate access. They differ in length: they are 10 and 8 miles long respectively, compared to the proposed approximately 14 miles for I-680 priced lanes. By way of comparison, peak SR 91 users pay about 48 cents/mile, and peak I-15 users pay 50 cents/mile for an average commute day (though it can reach up to $1/mile if extreme congestion dictates.

[11] For instance, HOT lane tolls for classes A through E for Alternative A-3 with an HOV 2+ carpool policy in 2025 in the southbound direction are, $5.01, $4.17, $3.28, $1.92, and $.02, respectively. Similarly, HOT lane tolls in the northbound direction for rate classes A through E are $6.99, $4.65, $1.76, $.80, and $.01 for Alternative A-3, in 2025, under a HOV 2+ carpool policy. The resulting weighted average toll rate is $1.56 in 2025, for this Alternative and carpool policy.

These lower per-mile figures for I-680 are likely a consequence of several factors, including differences in corridor congestion levels, differences in values of travel time, differences in carpool volumes and policies, and differences in operational objectives of the tolling. Higher tolls and higher revenues likely could be charged than are modeled here if (1) values of time evolve to be higher than assumed by the MTC model, and (2) policy makers are willing to reduce the volume of users for additional revenue. The modeled results indicate that the tolls contemplated for I-680 are certainly within a reasonable range of similar facilities and within a range that Bay Area users are willing to pay for improved service.

Table 8-4 shows toll estimates for Alternative A-4 in 2002, 2006, and 2025. Alternative A-4 differs from Alternative A-3 in that travelers would be allowed an opportunity to enter or exit the HOT lane at both the beginning and middle of the HOT lane. In the southbound direction the first segment (Southbound Segment 1) of the HOT lane that travelers approach is at the northern end of corridor, while the second southbound segment (Southbound Segment 2) is located at the southern end of the corridor. Similarly, the first northbound segment (Northbound Segment 1) that travelers see as they enter the corridor heading north is at the southern end of the corridor, while the second northbound segment (Northbound Segment 2) is located at the northern end of the corridor. The northbound segments 1 and 2 have distances of 7.1 and 6.9 miles, respectively. Segments 1 and 2 in the southbound direction span a distance of 8.6 and 5.4 miles, respectively.

Table 8-4: Toll Estimates for Alternative A-4 in 2002, 2006, and 2025 under HOV 2+ and HOV 3+ Carpool Policies

	Alternative A-4 HOV 2+			Alternative A-4 HOV 3+		
	Seg 1	Seg 2	Seg 1 & 2	Seg 1	Seg 2	Seg 1 & 2
Tolls in 2002 in 2002 Dollars						
PM Peak Toll in Peak Direction (NB)	$ 1.87	$ 1.30	$ 3.19	$ 2.73	$ 2.22	$ 4.99
PM Peak Toll in Peak Direction (NB) per Mile	$ 0.23	$ 0.22	$ 0.23	$ 0.34	$ 0.37	$ 0.36
AM Peak Toll in Peak Direction (SB)	$ 1.86	$ 0.75	$ 2.62	$ 3.37	$ 1.08	$ 4.47
AM Peak Toll in Peak Direction (SB) per Mile	$ 0.23	$ 0.13	$ 0.19	$ 0.42	$ 0.18	$ 0.32
Average Toll (both directions, all times of day)	$ 0.31	$ 0.18	$ 0.49	$ 0.51	$ 0.29	$ 0.80
Average Toll per Mile (both directions, all times of day)	$ 0.04	$ 0.03	$ 0.04	$ 0.06	$ 0.05	$ 0.06
Tolls in 2006 in 2002 Dollars						
PM Peak Toll in Peak Direction (NB)	$ 1.93	$ 1.53	$ 3.52	$ 2.69	$ 2.51	$ 5.29
PM Peak Toll in Peak Direction (NB) per Mile	$ 0.24	$ 0.26	$ 0.25	$ 0.34	$ 0.42	$ 0.38
AM Peak Toll in Peak Direction (SB)	$ 2.10	$ 0.75	$ 2.87	$ 3.75	$ 1.04	$ 4.84
AM Peak Toll in Peak Direction (SB) per Mile	$ 0.26	$ 0.12	$ 0.20	$ 0.47	$ 0.17	$ 0.35
Average Toll (both directions, all times of day)	$ 0.37	$ 0.22	$ 0.59	$ 0.60	$ 0.34	$ 0.94
Average Toll per Mile (both directions, all times of day)	$ 0.05	$ 0.04	$ 0.04	$ 0.08	$ 0.06	$ 0.07
Tolls in 2025 in 2002 Dollars						
PM Peak Toll in Peak Direction (NB)	$ 2.24	$ 3.33	$ 5.57	$ 2.49	$ 4.53	$ 7.02
PM Peak Toll in Peak Direction (NB) per Mile	$ 0.28	$ 0.56	$ 0.40	$ 0.31	$ 0.75	$ 0.50
AM Peak Toll in Peak Direction (SB)	$ 3.71	$ 0.75	$ 4.47	$ 6.17	$ 0.88	$ 7.06
AM Peak Toll in Peak Direction (SB) per Mile	$ 0.46	$ 0.12	$ 0.32	$ 0.77	$ 0.15	$ 0.50
Average Toll (both directions, all times of day)	$ 0.83	$ 0.55	$ 1.38	$ 1.25	$ 0.73	$ 1.98
Average Toll per Mile (both directions, all times of day)	$ 0.10	$ 0.09	$ 0.10	$ 0.16	$ 0.12	$ 0.14

Note: Peak toll refers to rate class A.
Source: ECONorthwest from PB/MTC data

Surprisingly, the MTC model predicts slightly negative growth in traffic volumes for some links in the southern portion of the corridor network between 2000 and 2025. Consequently, our model predicts toll levels in the southern segments to experience little to negative growth. The MTC model projects significantly increased congestion in the northern portion of the facility, causing optimal tolls to increase significantly over time in this portion of the corridor. Once again, the tolls are well within the range of tolls in other HOT lane facilities: the highest per-mile tolls in the peak directions for both segments are 36 cents in 2002, 38 cents in 2006, and 50 cents in 2025.

Traffic Volumes under Optimal Tolling

Tables 8-5 and 8-6 show peak period, hourly HOT lane traffic volumes in 2000 and 2025 respectively for Alternatives A-3 and A-4 in both the northbound and southbound directions.

Table 8-5: Estimated HOT Lane Volumes after Optimal Tolling during the Peak Period (2000, Rate Class A in Vehicles/Lane/Hour)

	SOV/Light Trucks	HOV 2	HOV 3+
Alternative A-3 (HOV 2+) Hourly Traffic Volumes in Peak Rate Period			
North Bound	756	283	100
South Bound	578	506	119
Alternative A-3 (HOV 3+) Hourly Traffic Volumes in Peak Rate Period			
North Bound	427	396	99
South Bound	498	269	142
Alternative A-4 (HOV 2+) Hourly Traffic Volumes in Peak Rate Period			
North Bound, Seg 1	598	486	193
North Bound, Seg 2	456	656	250
South Bound, Seg 1	571	526	188
South Bound, Seg 2	571	323	141
Alternative A-4 (HOV 3+) Hourly Traffic Volumes in Peak Rate Period			
North Bound, Seg 1	415	393	189
North Bound, Seg 2	273	474	249
South Bound, Seg 1	210	537	181
South Bound, Seg 2	316	375	135

Source: ECONorthwest from PB/MTC data

Table 8-6: Estimated HOT Lane Vehicle Volumes after Optimal Tolling during Peak Period (2025, Rate Class A in Vehicles/Lane/Hour)

	SOV/Light Trucks	HOV 2	HOV 3+
Alternative A-3 (HOV 2+) Hourly Traffic Volumes in Peak Rate Period			
North Bound	741	408	169
South Bound	431	906	219
Alternative A-3 (HOV 3+) Hourly Traffic Volumes in Peak Rate Period			
North Bound	486	339	165
South Bound	513	263	312
Alternative A-4 (HOV 2+) Hourly Traffic Volumes in Peak Rate Period			
North Bound, Seg 1	553	565	233
North Bound, Seg 2	473	821	364
South Bound, Seg 1	361	1,150	272
South Bound, Seg 2	365	704	178
Alternative A-4 (HOV 3+) Hourly Traffic Volumes in Peak Rate Period			
North Bound, Seg 1	424	331	234
North Bound, Seg 2	355	460	366
South Bound, Seg 1	477	346	388
South Bound, Seg 2	392	236	252

Source: ECONorthwest from PB/MTC data

Travel Times and Speeds under Optimal Tolling

Tables 8-7 and 8-8 show the travel times and speeds that correspond to the peak period under optimal tolling in the northbound and southbound directions in 2000 and 2025, respectively. Speeds on the HOT lanes are very near free-flow speeds when optimal pricing is implemented. At toll levels below those presented here, HOT lane speeds would decrease to some degree, because more vehicles would be attracted to the HOT lanes.

Table 8-7: Estimated Travel Times and Speeds with Optimal Tolling during Peak Period (Rate Class A) in 2000

	HOT Lane Travel Time (min.)	HOT Lane Speed (mph)	Mixed Flow Travel Time (min.)	Mixed Flow Speed (mph)
Alternative A-3 (HOV 2+) Hourly Traffic Volumes in Peak Rate Period				
North Bound	15.6	58.4	34.1	26.6
South Bound	15.9	57.4	27.7	33.0
Alternative A-3 (HOV 3+) Hourly Traffic Volumes in Peak Rate Period				
North Bound	15.1	60.3	35.7	25.4
South Bound	15.1	60.4	30.3	30.1
Alternative A-4 (HOV 2+) Travel Time and Speeds in Peak Rate Period (Seg 1 and 2)				
North Bound	16.5	55.0	29.6	30.7
South Bound	15.9	57.6	26.6	34.4
Alternative A-4 (HOV 3+) Travel Time and Speeds in Peak Rate Period (Seg 1 and 2)				
North Bound	15.2	59.9	34.7	26.2
South Bound	15.1	60.5	31.6	28.9

Source: ECONorthwest from PB/MTC data

Table 8-8: Estimated Travel Times and Speeds with Optimal Tolling during Peak Period (Rate Class A) in 2025

	HOT Lane Travel Time (min.)	HOT Lane Speed (mph)	Mixed Flow Travel Time (min.)	Mixed Flow Speed (mph)
Alternative A-3 (HOV 2+) Hourly Traffic Volumes in Peak Rate Period				
North Bound	16.5	55.0	47.5	19.1
South Bound	19.5	46.8	39.2	23.3
Alternative A-3 (HOV 3+) Hourly Traffic Volumes in Peak Rate Period				
North Bound	15.2	59.9	41.2	22.0
South Bound	15.5	58.9	39.8	23.0
Alternative A-4 (HOV 2+) Travel Time and Speeds in Peak Rate Period (Seg 1 and 2)				
North Bound	18.8	48.3	40.9	22.2
South Bound	20.6	44.2	37.7	24.2
Alternative A-4 (HOV 3+) Travel Time and Speeds in Peak Rate Period (Seg 1 and 2)				
North Bound	15.4	59.0	42.0	21.6
South Bound	15.5	58.8	43.4	21.1

Source: ECONorthwest from PB/MTC data

Financial Feasibility

Assessing the financial feasibility of the HOT lane alternatives under a HOV 2+ and HOV 3+ carpool policies is a critical portion of this study. Feasibility is determined by calculating the optimal tolls that would be charged on the HOT lane, aggregating them over various hours of the day and week, annualizing them, and then aggregating the revenues across a 20-year time period assumed in the analysis. The actual life of the facility, however, is likely to be much greater than 20 years.

The HOT Lane Alternatives modeled here are Alternative A-3 (without an intermediate access point) and Alternative A-4 (with an intermediate access point). A HOT lane Alternative involving continuous access (akin to a pure HOV lane) was not modeled. The financial analysis is not extended beyond 2025 in this analysis. Furthermore, the analysis further assumes that the HOT Lanes will be operational no sooner than 2006.

Summary of Revenue Under Optimal Tolling

Using the MTC/TOM optimization and extrapolation process, each alternative was modeled for 2000 and 2025. For each alternative modeled, annual revenue grows at a rate between four and five percent between 2000 and 2025. The implicit growth ràte derived through our modeling is used to interpolate[12] annual revenue between 2006 and 2025. When aggregated to annual values, the tolls generate between $6.3 and $14.7 million dollars in 2006, in terms of 2002 dollars.

For both Alternative A-3 and Alternative A-4, we find that the choice of carpool policy has a dramatic effect on the revenue potential of the HOT lane facility. Not surprisingly, substantially more revenue is generated under a HOV 3+ carpool policy, because fewer vehicles would be eligible to use the lanes for free. We also find that Alternative A-4 would generate less revenue than Alternative A-3 under comparable carpool policies.

Table 8-9 shows annual revenue each year of the analysis period in 2002 dollars.[13] The net present value in 2002 of the stream of revenue generated through 2025 is calculated assuming a 4% real discount rate. The present value calculation is useful in cases where the costs of developing the facility, implementing the HOT lane technology and/or underwriting transit service development are to be financed with bonds. As the table indicates, between approximately $100 million and $245 million in such bonding could be supported today by toll revenues, according to the toll optimization calculations.[14]

[12] This interpolation utilizes a non-linear interpolation procedure, since revenues grow non-linearly.

[13] The annual revenue projections reported in Table 8-9 have been adjusted to reflect a 14.0 mile HOT lane length.

[14] The assumed four percent real discount rate is consistent, assuming a three percent inflation rate, with a nominal bonding rate of approximately seven percent.

Table 8-9: Annual Revenues for Alternatives A-3 and A-4 (Millions of 2002 Dollars)

	Alternative A-3 HOV 2+	Alternative A-3 HOV 3+	Alternative A-4 HOV 2+	Alternative A-4 HOV 3+
2002	$0.0	$0.0	$0.0	$0.0
2003	$0.0	$0.0	$0.0	$0.0
2004	$0.0	$0.0	$0.0	$0.0
2005	$0.0	$0.0	$0.0	$0.0
2006	$9.8	$14.1	$6.3	$14.7
2007	$10.1	$14.6	$6.5	$15.3
2008	$10.5	$15.1	$6.8	$15.9
2009	$10.9	$15.7	$7.0	$16.6
2010	$11.4	$16.2	$7.3	$17.3
2011	$11.8	$16.8	$7.5	$18.0
2012	$12.3	$17.4	$7.8	$18.8
2013	$12.7	$18.1	$8.1	$19.6
2014	$13.2	$18.8	$8.4	$20.4
2015	$13.8	$19.4	$8.7	$21.2
2016	$14.3	$20.2	$9.0	$22.1
2017	$14.8	$20.9	$9.3	$23.0
2018	$15.4	$21.7	$9.6	$24.0
2019	$16.0	$22.5	$10.0	$25.0
2020	$16.6	$23.3	$10.3	$26.0
2021	$17.3	$24.1	$10.7	$27.1
2022	$18.0	$25.0	$11.1	$28.2
2023	$18.7	$25.9	$11.5	$29.4
2024	$19.4	$26.9	$11.9	$30.6
2025	$20.1	$27.9	$12.3	$31.9
Total	$287.1	$404.4	$179.8	$445.0
NPV	$158.7	$224.2	$99.8	$245.2

Real Discount Rate assumption: 4.0%
Source: ECONorthwest from PB/MTC data

HOT Lane Operating Costs

Positive net operating income generated by the HOT lane can be used to support the construction of the facility or to fund other transportation improvements, such as more express bus service in the corridor. The amount of construction that can be supported by this revenue flow depends upon the rate at which future cash flows are discounted (to reflect the cost of funding construction of the facility) and the costs of operating the facility on an ongoing basis relative to the revenue it generates. The operating costs for Alternatives A-3 and A-4 are estimated to be approximately $1 million per year in 2002 dollars; this cost represents a conservative number, based on the most expensive of the electronic tolling options considered (see Chapter 5), including redundant toll readers on the corridor to discourage violators and provide backup in the event of malfunction of one reader.

Net Revenues Generated by HOT Lane Operating Income

In Table 8-10 below, the net present value of operating income is compared with the upfront capital cost requirements, including bond issuance fees, at various discount rates. (The incremental capital costs presented for Alternatives A-3 and A-4 are principally related to the electronic tolling and enforcement facilities and activities, necessitated by tolling in addition to free HOV access lanes.) As Table 8-10 indicates, net operating revenues could potentially support between $30 and $305 million of the proposed facility capital costs depending on the discount rate, Alternative, and carpool policy that is adopted. The shaded 4% Real Discount Rate, yielding income ranging from $83 to $228 million, is considered to be a realistic long-term rate, as discussed in the section below on Sensitivity of Feasibility Analysis to Alternative Assumptions.

Table 8-10: 20-year Cumulative Present Value of Net Operating Income, 2006-2025 (Millions of 2002 Dollars) *

Real Discount Rate	Alternative 3 HOV 2+	Alternative 3 HOV 3+	Alternative 4 HOV 2+	Alternative 4 HOV 3+
2%	$190	$276	$111	$305
3%	$164	$239	$96	$263
4%	$142	$207	$83	$228
5%	$123	$181	$72	$199
6%	$108	$158	$63	$174
7%	$95	$139	$55	$152
8%	$83	$123	$49	$134
9%	$74	$109	$43	$119
10%	$65	$96	$38	$105
11%	$58	$86	$34	$94
12%	$52	$77	$30	$84

Source: ECONorthwest from PB/MTC data

* Based on costs associated with Toll Collection option consisting of ETC, 1 lane in each direction, 1 intermediate access, and 4 additional readers. Initial capital costs are $3,241,000 and annual operating costs are $1,018,000. Costs assume a system upgrade every 5 years, with a 40% capital replacement factor. System upgrade also includes 50% of the original system design costs.

Sensitivity of Feasibility Analysis to Alternative Assumptions

Table 8-10 raises several questions that should be addressed in considering the financial feasibility of the proposed project:

- What is the appropriate discount rate to use? From Table 8-10 it is clear that the higher the discount rate assumption, the less financially feasible is the proposed project.
- What would be the effect of continued personal income growth on the financial feasibility of the project?

The issue of the appropriate discount rate is fairly straightforward. The discount rate should reflect the likely interest rate at which this project can be financed. Even though public projects can be financed through tax-exempt bond issues (which enjoy, consequently, lower bond rates) economists generally urge that *private* funding rates be employed in evaluating even public projects. The reason is that the lower, public bond rate is achieved through losses in taxable revenue that have to be made up out of higher taxes on private income.

However, the relevant discount rate in this case is the *real* discount rate (i.e., the rate that would exist if inflation did not exist), because inflation is implicitly assumed to be zero in the toll and cost analysis. Consequently, a discount rate in the range of 3% to 4% is reasonable; this range corresponds to a nominal discount rate range of approximately 6% to 7%, for example, if inflation were 3% per annum.

The second issue concerns the effect of rising incomes over time. The analysis presented here adopts the MTC convention of no assumed real (inflation-adjusted) income growth over time. However, in the likely event, based on historical trends in the Bay Area, that real income actually grows, the real value of time grows accordingly. Since higher values of time generally increase the tolerance for tolls proportionately, the toll levels reported here could be increased accordingly to reflect the higher toll-paying tolerance. In this analysis, we have assumed no real wage growth, and thus these toll levels and revenue estimates are probably biased downward and are conservative.

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CHAPTER 9: OPERATIONAL ANALYSIS

The operational analysis was conducted to assess the traffic operations characteristics of using the planned 2+ HOV lanes on southbound and northbound I-680 (SR 84 to Calaveras – SR 237) as HOT lanes as well as HOV lanes. Vehicles not meeting the criterion for the minimum number of occupants during peak periods would be allowed to use the express lanes for a toll. A number of alternatives were assessed for both 2000 and 2025 conditions. The alternatives were defined as having either one or two entry and exit points from the HOT lanes, with options of either 2+ occupant or 3+ occupant vehicles paying no toll. These alternatives were compared with two non-tolled alternatives: (1) southbound HOV 2+ only (existing/no build), and (2) both southbound and northbound HOV 2+. The purpose was to determine whether the proposed modification of these HOV lanes to HOT lanes would significantly impact freeway operations.

They were defined as follows:

- No Build
- Alternative A-1: 2+ HOV-only
- Alternative A-2: 2+ HOV/HOT, continuous access (not modeled)
- Alternative A-3: 2+ HOV/HOT, no intermediate access, 2+ HOV definition
- Alternative A-3: 3+ HOV/HOT, no intermediate access, 3+ HOV definition
- Alternative A-4: 2+ HOV/HOT, one intermediate access, 2+ HOV definition
- Alternative A-4: 3+ HOV/HOT, one intermediate access, 3+ HOV definition

Calibrated AM peak period and PM peak period FREQ models were developed for I-680 based upon 2001 conditions (volumes and floating car runs) and then used the calibrated model output to conduct an operational analysis on 2000 and 2025 demand forecasting MTC model output. Using the demand model forecasts for 2000 and 2025 allowed for modeling consistency between the two analysis years.

Findings

The analysis shows that the HOT lane, under some scenarios, results in slightly worse traffic congestion than continuous HOV lane operations, due to the constraints imposed by limited exits from the HOT lane. HOT lane operations create additional capacity constraints that can be mitigated. Mitigation can be achieved through the addition of short segments (totaling approximately 0.5 mile) of weaving lanes at the exit locations of the HOT lanes for southbound travel, and extending the existing auxiliary mixed-flow lane northbound approximately 1.5 miles from the truck scales to the HOT lane terminal interchange of I-680 with SR 84 (see Figure 9-1). Once mitigation is in place, two of the HOV/HOT lane alternatives operate slightly better than the HOV-only alternative and much better than No Build. Comparing all the build alternatives to No Build, 2025 travel times in the southbound mixed-flow lanes are reduced from 80-100 minutes to 25-45 minutes. The same positive effect occurs in the northbound PM direction. Specific findings for each peak direction and horizon year follow. Complete results are found in Appendix E, *Operations Analysis.*

In **2000 southbound**, the specific key findings are:

- Comparing the HOV-only Alternative A-1 with the HOT lane alternatives, the mixed flow lane speeds for HOT lanes are between 26% and 38% lower.
- The reason for the additional congestion and lower average speeds compared to HOV-only is that the HOT lanes constrain all vehicles to exit only at one or two locations, and this concentrated weaving reduces the per-lane capacity of I-680 at the single or two HOT lane egress points. This reduction in capacity occurs with the HOV lanes as well, though not as severely.
- In all cases in 2000, the HOV and HOT lanes operate at speeds at 65 mph.

In **2000 northbound**, the specific findings are:

- All build alternatives show mixed flow lane speeds over 57.7 mph (compared with 43 mph for No Build).

- All HOV and HOT Alternatives show speeds of 65 mph in the HOV/HOT lanes.
- There are potential bottlenecks with the HOT lane alternatives at Mission Boulevard (SR 238) and at SR 84, but with the 2000 forecast volumes these bottlenecks do not significantly impact average travel speeds; the average overall facility speeds range from 58.1 to 61.9 on the HOT alternatives, compared to 62.3 mph on the HOV-only alternative.

In **2025 southbound**, the specific key findings are:

- Average mixed flow lane and HOV/HOT lane speeds for HOT alternatives are slightly higher (between 1% and 9%) for HOT alternatives than HOV-only, except for Alternative A-4: 2+ (intermediate access), where they are 8% lower. The same general pattern is true for the total facility: 3 to 6% higher speeds for HOT than for HOV-only, except for Alternative A-4: 2+ (7% lower speed).
- Person-throughput, as measured by person-miles traveled, for HOT alternatives between 1% and 8% higher than for HOV-only.
- The HOV and HOT lanes are at or near capacity over the Sunol Grade, but continue to operate at 62 to 65 mph for the HOV2+ scenarios
- For the HOV 3+ HOT lane alternatives, the HOT lanes operate at about 60% of capacity.

In **2025 northbound**, the specific key findings are:

- The HOT lanes perform better than the HOV 2+ alternatives in all cases, except for the HOT 2+ with intermediate access (A-4:2+). The HOT lane alternatives result in mixed-flow lane speeds ranging from 34 mph to 44 mph while the HOV 2+ alternatives show speeds of 36.6 mph in the mixed-flow lanes. Comparing total facility average speeds, the HOT lane alternatives range from 36 mph to 45 mph, while the HOV-only is 39 mph, and No Build is 25 mph.
- The HOV/HOT 2+ lanes will operate near capacity while the HOV/HOT 3+ will operate at around 60% of capacity. In both cases, the HOV/HOT lane speeds are between 63 and 65 mph.
- All alternatives show the mixed-flow lanes operating at Level of Service F, while the HOV/HOT lanes operate above 60 mph.

Generally, HOT lanes will perform as well as HOV-only lane alternatives in 2000 for northbound PM peak period conditions. In 2025 most HOT alternatives will perform much better than HOV-only alternatives for northbound PM peak period conditions. In all cases, the congested conditions in the mixed-flow lanes can be substantially mitigated with the addition of a short weaving lane to offset the capacity reductions to mixed-flow lane capacity caused by egress from the HOV/HOT lanes. The nature of this mitigation is explained in more detail below under Restoring Capacity.

Restoring Capacity

A capacity constraint occurs with the implementation of the left lane as an HOV/HOT lane, where all HOV/HOT vehicles seek to exit the freeway and need to weave to the right over a relatively short distance. This intensified weaving reduces the capacity of the mixed-flow lanes below the typical effects of on-ramps at interchanges. The suggested mitigation of adding one mixed-flow lane for short distances at certain locations (Figure 9-1) is to offset the reduced lane capacity created by the HOV/HOT lane operations. The resulting total vehicle peak period capacity of four-mixed flow lanes at the HOV/HOT lane bottlenecks is approximately equal to the vehicle capacity of three mixed-flow lanes without the intensified weaving.

In this case, adding the short stretch of additional weaving lane primarily serves to return mixed-flow lane capacity to the three-lane levels that would exist without the HOV/HOT lanes. The HOV lane operations allow drivers to enter and to exit the HOV lane all along the corridor, so the weaving impact on mixed-flow lane capacity of an HOV-only, continuous access facility is somewhat less concentrated at one or two locations than that of HOT lane alternatives.

The operation of northbound traffic in the PM peak period is better than southbound traffic in the AM peak period. This is because once traffic gets past Mission Boulevard (SR 238), there is a truck climbing lane all the way over the grade and beyond (the southbound lane is dropped at the top of the grade), and more vehicles leave I-680 than get on north of Mission Boulevard, especially to eastbound SR 84. Traffic is diverging in the afternoon, and it converges in the morning. Traffic converging onto I-680 from the Sunol Grade all the way to Calaveras is a primary reason for the bottleneck at the south end of the corridor.

Comparison of Alternatives after Restoring Capacity

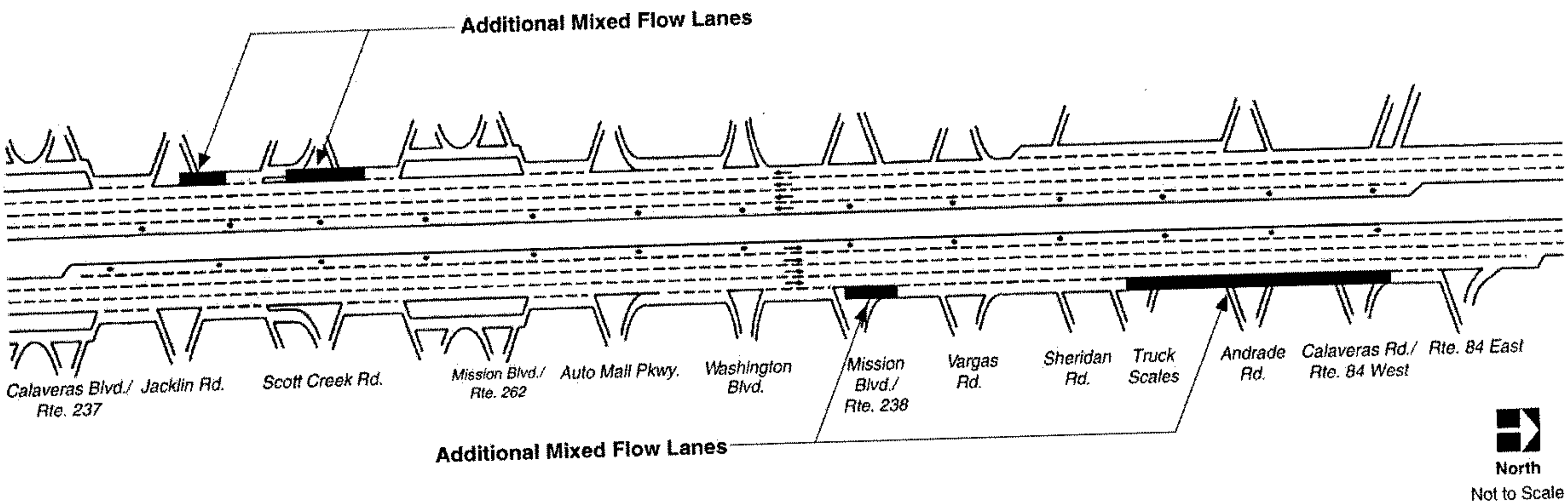
A sensitivity analysis was done on the 2025 scenarios to compare the various alternatives on the assumption that the mitigation described above is adopted and capacity restored. The findings are that HOV-only has higher average speeds than the HOV/HOT alternatives in the southbound direction, but lower in the northbound direction. In terms of person-throughput (as measured by person miles traveled), the results are similar in some respects: higher for HOV-only than for HOV/HOT southbound, but lower northbound in Alternative A-4 3+ and virtually identical in A-3 3+.

All HOV-only and HOV/HOT scenarios perform much better than No Build in terms of average speed. No Build average speeds range from 24.9 to 32.1 mph, while HOV-only and HOV/HOT range from 41 to 55.4 mph.

Operational Conclusions

In sum, mitigation to restore capacity causes all scenarios to perform considerably better. The HOV-only alternative in 2025 performs better than HOV/HOT southbound, but generally not as well northbound. The HOV-only <u>and</u> HOV/HOT alternatives perform considerably better than the No Build, as measured by average speeds and person throughput (person-miles-traveled). HOV-only and HOV/HOT average speeds in the HOV/HOT lanes are consistently above 62 mph, and generally at 65 mph, demonstrating that users of those designated lanes will experience good performance under all scenarios and there is little risk of degrading HOV lane service by making the lanes available for toll-paying users.

Properly designed, HOT lanes appear to be operationally feasible and perform comparably with HOV-only lanes in terms of average speeds and moving people through the corridor. However, the limited access feature of all HOT alternatives does remove some of the HOV users who would otherwise use the HOV/HOT lanes, because their origin or destination is incompatible with the ingress/egress locations.



Restoring Capacity At Ingress/Egress Locations
Figure 9-1

CHAPTER 10:
HOV/HOT LANE CAPACITY AND VOLUMES

An essential question to answer in consideration of any HOT lane is, "How much capacity is available to sell in the HOV lane?" The answer to that question helps determine the pricing structure, how much revenue can be generated, and the public acceptability of the project. If there is not sufficient available capacity, then the policy-makers and public will question whether the HOT lane provides enough benefits to make installing toll collection equipment worthwhile. On the other hand, if there is there is a substantial amount of capacity (i.e., severely underutilized HOV lanes), then it raises the question about whether the HOV lane itself is necessary, due to a lack of either time savings or demand.

The answer to the capacity question is complicated by several uncertainties: (1) the theoretical "normal capacity" of an HOV lane is itself subject to different interpretations; (2) travel forecasting and operational analysis depend upon assumptions that may or may not be proven accurate when tested against reality after HOV or HOV/HOT are placed into operation; (3) different geometrics, interchange spacing, and freeway configuration choices (especially lane separation treatments) can have an impact on what constitutes "capacity" in a given corridor; and (4) different, and sometimes competing, values can be served by allowing more or less vehicles into the HOV/HOT lanes. The following discussion addresses each of these issues as they are manifested in the I-680 findings in this report and existing literature on HOV lanes.

What is the Capacity of an HOV lane?

A conventional mixed-flow freeway lane, according to Caltrans standards, has a capacity of 1900-2200 vehicles per hour (vph), with the variability arising from factors such as shoulder widths, sightlines, grades, and spacing of interchanges. The capacity of an adjacent HOV lane must be viewed differently from a mixed-flow lane, because one purpose of an HOV lane is to provide its users with a reliable high level of service so they can count on speeds at or near the speed limit nearly all the time, barring incidents or extraordinary circumstances. This is generally referred to as Level of Service C. The current maximum capacity cited in the Metropolitan Transportation Commission's HOV Lane Master Plan is 1600 vph. Caltrans has used standards ranging from 1600 to 1800 vph, depending upon whether there were one or two HOV directional lanes available. A recent study for Los Angeles MTA used a maximum threshold of 1650 vph. The Federal Highway Administration's Guide for HOT Lane Development cites 1700 vph as a safe range.

Observation of actual HOV lane operations has shown higher volumes with no degradation of service. SR 91 (an HOV/HOT lane) has operated acceptably at 1800/vph. A recent Orange County Study shows peak hour volumes up to 1700 vph, though intermittent congestion in the HOV lanes is observed. A January 2003 observation of HOV lanes on southbound Interstate 880 in Alameda County (between Route 238 and SR 92) counted 2000 vph in the HOV lane, with average speed of 55 mph.

Thus, the determination of capacity is subject to some interpretation, which means that HOV lane "excess capacity" available for HOT vehicles can vary depending upon what assumptions are used and what risk of occasional reduction of service level is deemed acceptable. A conservative assumption would be to place the capacity on I-680 HOV lanes in a range between 1600 and 1700 vph. Because this proposal for an HOV/HOT lane on I-680 provides standard lane and shoulder widths, limited access and buffer through striping, it provides the opportunity to achieve the high end of this capacity range. While not as definitively separated from adjacent slower-moving traffic as they would be with a concrete barrier, vehicles in the HOV lane will be inclined to maintain relatively higher speeds than they would if there were continuous access. According to the Orange County study of buffer-separated HOV lanes, vehicles in the HOV lanes feel more comfortable that slower moving cars in the mixed-flow lanes will not maneuver in front of them unexpectedly. The higher speeds are conducive to higher capacity.

Travel Forecasting

The travel forecasts for year 2000 (i.e., assuming HOV lanes were in place in year 2000 traffic conditions) show highest peak hour volumes for the HOV-only alternative between 1093/vph and 1428/vph. Year 2025 show volumes highest peak volumes between 1232/vph and 1841/vph. This assumes a continuous access HOV lane.

Due to the limitations of the demand model, there is a potential for overestimation of HOV trips. The demand model "creates" HOV trips in response to a time-savings offered by HOV facilities. For the most part, this is a reasonable assumption: carpools will form when offered the benefit of a shorter trip. However, in reality there may not be an unlimited supply of carpoolers. An individual's ability to form a carpool is limited by the availability and willingness of another household member or neighbor to share a ride. The demand model is not capable of modeling such complex inter- and intra-household relationships. As a result, there is a potential for overestimating the number of carpoolers even when an HOV lane offers a substantial time savings. Although no formal testing of this hypothesis has been performed, anecdotal evidence is available through inspection and comparison of the HOV predicted and actual volumes on nearby I-880. For example, actual traffic counts on I-880 for dates in the first week of January 2003 show approximately 1700/vph in the HOV lane, while the model predicts approximately 2000/vph – an overestimation of about 15%. While these results do not offer conclusive evidence of HOV volume overestimation, they do point in that direction.

Another factor that forecasting may not adequately take into account is the impact of HOT lane systems on violation rates. With continuous access on a conventional HOV lane, violation is easy – the driver can slip in and out of the line at any point, depending upon the perception of enforcement level and the chance of being apprehended. According to a recent report, violation rates on Bay Area continuous access freeway HOV lanes in 2001 averaged 6.5% for the AM peak direction and 4.5% in the PM peak. Some freeway segments have violation rates as high as 19.1% in the AM peak. HOT lanes, on the other hand, have "true" (i.e., after apparent but, upon verification, not actual violations are discarded) violation rates of approximately 2.6% for I-15 in San Diego and about 1.9% for SR 91 in Orange County. Because enforcement would be greatly improved by enhanced highway patrol presence, visible readers and surveillance cameras, and clearly marked striping and signage warnings to potential violators, it can be anticipated that violation rates will be reduced in the proposed limited access HOT lane configuration. If the number of violators is reduced, the available excess capacity for legitimate HOT vehicles is increased.

Thus, the travel forecasts are somewhat more likely to understate than overstate the capacity that is "excess" and available to sell to toll-payers, due to overestimation of the number of carpools that will actually use the HOV lane. However, it must be noted that the revenue model for the HOT lane accepts the results of the travel forecast model and does <u>not</u> make the assumption that there is more excess capacity than the forecast model indicates. Thus, the revenue estimates could be too low, if there is actually more capacity to sell than predicted by the model.

As part of its HOV Master Plan Study Alternative (and independent of this study), the MTC undertook a travel forecast of corridor-level performance of potential HOT lanes in the AM peak, assuming a 3+ carpool policy. The results were reported in a February 27, 2003 memo. It analyzed nine candidate HOT lane potential corridors, including southbound I-680 in Alameda and Contra Costa counties, for a year 2010 planning horizon on a sketch planning basis. In general, the analysis showed that, under a 3+ carpool policy, introduction of HOT lanes would increase average speeds by up to 35% in the mixed-flow lanes and decrease speeds by 4% in the HOV/HOT lanes. I-680 was the corridor in which the benefits were the greatest, with an increase of 59% in average corridor speeds. This analysis assumed 1600/vph as a reasonable level that reflects an optimal use of a HOV/HOT lane without significant delay.[15]

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[15] *HOV Master Plan Study: Alternative 5: High Occupancy Toll (HOT) Lane Alternative*, Memorandum from Chuck Purvis & Rupinder Singh, February 27, 2003.

Freeway Configuration

Different freeway geometrics can have an impact on what constitutes freeway capacity. In the case of I-680 there are mixed impacts, with some factors pointing toward less capacity and some toward more capacity. This segment of I-680 is characterized by some fairly steep grades and more curves than the typical freeway; these factors tend to lessen the capacity by causing drivers to slow down.

On the other hand, compared to many other Bay Area freeways, there are relatively longer distances between interchanges and fewer vehicles getting on and off in this segment, due to the semi-rural nature of much of the freeway segment. This factor tends to increase capacity. In addition, the limited access feature of the proposed HOV/HOT lane would tend to increase capacity by providing a more clearly delineated separation from the adjacent mixed-flow lane and less turbulence caused by the constant weaving of vehicles in and out of the lane.

This report concludes that the positive and negative factors approximately neutralize one another and do not make any significant difference in determining capacity.

Values

Determining capacity is an art as well as a science, because the conclusion is partially determined by the degree of risk the managers of the freeway are willing to take and what values they are trying to maximize. For example, if the highest priority value is to have virtually no risk that the HOV lane will ever experience a slowdown as a result of too many vehicles (as distinct from traffic accidents), then the acceptable HOV lane capacity will be a lower number. However, if the dominant value is to provide access to a greater number of vehicles on the HOV lane, while accepting some risk of occasional slowdown, then the acceptable capacity number will be higher.

The best illustration of this tradeoff is when the number of 2+ vehicles in the HOV lane begins to bump up against the capacity limits and leads to reduction in speeds on some segments occasionally during the day; this is already occasionally the case on I-880. A simple solution to this phenomenon is to change the definition of a carpool from 2+ to 3+, because a large percentage (more than 50%) of users are 2-person carpools and would no longer be eligible. However, this is very difficult to do, because it would be hard to obtain public acceptance for such a change that would take away a benefit from a large number of current users. The implicit tradeoff in retaining a 2+ carpool policy, even in the face of some deterioration in service level and reliability, is that allowing more users to experience a benefit most of the time is of higher value than guaranteeing a smaller number of users a benefit all of the time. This is a policy choice and dilemma which will face Bay Area policy-makers in the future, if and when volumes on many HOV segments approach their limits and experience deterioration in service level.

Another question concerns the importance of the value of time for different users. Currently, freeway users need make no calculation about the value of their time as it relates to their driving behavior. Someone taking a non-essential trip to browse at the mall during the peak hour experiences the same speed and delay as someone who would lose his/her job as a result of being late on a particular trip, despite their vastly different values of time. Drivers who are able to form a carpool gain the benefit of the HOV lane, regardless of the value of the time saved, and those unable to form a carpool have no choice but endure the delay, no matter how costly.

The values question is: Does the benefit of providing an option allowing some drivers to pay when it is worthwhile to them outweigh the risk that, on rare occasions, too many vehicles may use the lane? The answer is not self-evident, and it depends upon whether or not the policy-makers view the introduction of an element of value-of-time into travel decisions as a worthy goal that merits taking an occasional risk to the HOV lane's level of service.

Conclusions on HOV Lane Carrying Capacity

The carrying capacity of a given HOV lane, and therefore the amount of excess capacity available for pricing, is not always easy to calculate. There are both physical and travel modeling variables that can lead to different conclusions, so uncertainty will always exist until the lane is actually constructed and in operation. Also, the decisions about lane separation treatment and limited vs. continuous access can have an impact on the effective capacity of the lane.

Introduction of a HOT lane concept is predicated on some capacity being available for a substantial period of time, in order to make the toll collection operation at least a break-even proposition that improves freeway utilization and hopefully produces net revenue for the overall transportation system. It is also predicated on the ability and willingness to adjust tolls quickly, so that the chance of inadvertently permitting too many vehicles to "buy into" the lane is minimized.

The most difficult decision for policy-makers concerning capacity on HOV lanes will be when the 2+ carpool policy leads to such high volumes that the levels of service on HOV lanes are frequently reduced to the point where there is little speed or reliability advantage to using those lanes. That is the point at which policy-makers will know from irrefutable empirical evidence that the capacity of that a particular freeway segment has been exceeded.

The year 2025 forecasts indicate that the decision to convert to the 3+ carpool definition will be confronted by that date or perhaps several years earlier, as some I-680 segments reach volumes over 1800 vph in the HOV-only scenario and nearly 1800 in one of the of HOT scenarios (Alternative A-4, 2+).

If the difficult decision is made to move from a 2+ to a 3+ carpool policy, decision-makers know they will take the risk of moving from overutilization of the HOV lane to severe underutilization. That would entail the problem of sending many vehicles back into the mixed-flow lanes and increasing public frustration. In that circumstance, the availability of a HOT lane system in place or ready to install could greatly mitigate the underutilization problem and perhaps increase the public acceptance of the modified carpool policy. An appropriately priced HOT lane could restore balance to the freeway operation, by better matching capacity with demand and adjusting the toll levels to make sure that the overutilization problem does not return.

Interim Traffic Counts

Beginning in January 2003 Caltrans conducted frequent traffic counts on the interim southbound HOV lane to determine the number of vehicles using the HOV and mixed-flow lanes. The purpose was to compare the actual volume of vehicles with the forecast volume, in order to verify whether there is sufficient capacity available to sell. The average of the three most recent counts (March-April 2003) show the following averages.

Table 10-1: Year 2003 Traffic Counts

	HOV Lane	Mixed-Flow Lanes, per lane (3 lanes)
Total peak period (6-9:00 AM)	1624	5365
Average per hour during peak period	541	1788
Peak one-hour	555	1861

These preliminary counts indicate that there is less traffic on the corridor segment than is forecast by the MTC model for year 2000, especially in the HOV lane. This suggests that there is considerable capacity to sell in the HOV lane, perhaps space for as many as 1,000 more vehicles, because the highest hour volume in any count (555) for the HOV lane is well under the 1600-1700 vph that is generally considered to be the capacity of an HOV lane.

On the other hand, the fact that the mixed-flow lanes are relatively uncongested even in the peak hour (1861 vph), with typical speeds slightly above 55 mph, suggests that fewer drivers than forecast might be willing to pay a toll to use the HOV lane. It is likely, however, that both HOV and mixed-flow volumes are unnaturally low due to the severe economic slump currently being experienced by Silicon Valley, the destination of most of the peak-period users. Thus, long-term planning for the I-680 corridor will proceed on the assumption that the economy will eventually recover and that the severe traffic congestion and delays of the late 1990's will recur and worsen. Planning for the HOV and possible HOT lanes is conducted for a major investment and a 25-year horizon.

Volume Forecasts and Observed Experience

Travel forecasting, as well as preliminary traffic counts on the southbound HOV lane, indicate that substantial capacity will be available to permit introduction of a HOT lane concept. Year 2000 forecasts show considerable excess capacity under all scenarios; around 1200 vph for HOV2+ carpool policies and 900 vph for HOV3+ carpool policies. The year 2025 forecasts show HOV/HOT lanes much closer to reaching capacity: 1325-1775 vph under HOV2+ policy, 1200-1550 vph under HOV3+ policy. The most problematic case is where the carpool policy is 2+ and intermediate access is permitted. It must be emphasized that, in those scenarios where exceeding capacity is forecast, an adjustment of the toll level (higher than the level deemed "optimal" by the model) can readily reduce the number of vehicles to maintain a safe cushion below theoretical capacity. A pricing system, if properly and regularly adjusted to real world conditions, can assure that the HOV/HOT lane does not reach capacity and degraded levels of service.

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CHAPTER 11:
POLICY CONSIDERATIONS

Comparing HOT Lanes and HOV-only Lanes

Additional lane capacity on the I-680 corridor can be built as conventional, continuous access HOV-only lanes, regardless of the financial feasibility of the HOT lane option. This raises the key issue of whether the HOT lane offers efficiency or other advantages over a pure HOV lane. Although HOT lanes and limited access HOV lanes exist in southern California, free and continuous access HOV lanes are the norm in northern California and HOT lanes would represent a departure for both policy-makers and the driving public.

From the purely economic viewpoint, the pricing of lanes is usually preferred to not pricing lanes, because pricing assures that roads are used by drivers at times and with frequency that is in proportion to its value to them. So long as users do not bear directly the cost of their use— especially during the highly congested times— one can never be sure whether resolving congestion through expensive, new construction of capacity is warranted, because users are only facing their own delay cost (and the small average "toll" that is implicit in gasoline taxes) and not the delay cost their road usage imposes on others. The benefits of use are best reflected in a user's willingness to pay for the service, and this can only be measured with a system of pricing.

These broad, efficiency implications aside, there could be a concern that making the facility a limited-access HOV plus HOT lane rather than a continuous access HOV lane may cause somewhat fewer carpools to use the lane, for two reasons: (1) some former HOVs would break up and become toll-paying SOVs to take advantage of the new HOT lane option; (2) HOVs would prefer to enter or exit the HOV lanes at points other than the limited ones permitted. The modeling analysis conducted in this study, comparing a limited access HOV vs. a limited-access HOT lane, indicates that there would be a 12% reduction in carpools if the HOT lane option were available. However, the limited-access feature, rather than pricing, would reduce carpool usage of the lane by an additional 11% in Alternative A-4 (intermediate access available) and 26% in Alternative A3 (no intermediate access), presumably because some of the vehicles would prefer to enter or exit at a location not permitted in the limited access scheme.

Nevertheless, actual experience in southern California differs from the modeling results and indicates that the use of limited ingress/egress has not been significant impedance to carpooling, as the limited access HOV lanes in Los Angeles and Orange counties carry some of the highest carpool volumes anywhere. Actual experience In San Diego has shown that the number of carpools has <u>increased</u> substantially since the advent of HOT lanes on I-15. In reality, time saving is generally the motivation for discretionary carpool formation. If time saving is reduced or lost due to overutilization of the HOV lane, then carpool formation is discouraged.

Both total travel-time efficiency (i.e., reduced delay) and person-throughput could be increased under HOT/HOV compared to the HOV-only alternative, depending in part upon how the toll revenues are used. For example, if revenues generated by HOT lanes are used to fund greatly enhanced express bus service in the same corridor, then new transit riders could be attracted, including those who would otherwise be using the mixed-flow lanes or unable to make the trip due to unavailability of a car or the excessive time delays.

By relieving demand on the mixed-flow lanes, more capacity is freed up for additional trips to be accommodated in those lanes, if the demand is present. The travel demand modeling in this study did not assume any more transit service in the corridor as a result of revenue from HOT lanes, but it is a logical conclusion, to be confirmed or rebutted in future forecasting and observed experience, that offering more transit service would increase ridership and reduce the number of vehicles on the freeway.

Combining Freeway Management Strategies

The mobility and efficiency advantages of a designated HOV lane are preserved by restricting lane use to vehicles with the requisite number of persons. This strategy is now widely applied in the Bay Area and is generally accepted and understood. But this strategy represents only one of three traffic management tools commonly employed outside this region to effectively preserve mobility on a dedicated lane. The other tools accompanying user restrictions are (1) access location restrictions and (2) pricing strategies.

Access restrictions are widely applied in southern California (Los Angeles, Orange, Riverside and San Bernardino counties) as a means of limiting HOV demand to longer distance trips and promoting ingress and egress only at specified locations. This strategy precludes unconstrained weaving to, from, and across the mixed-flow lanes. The limited access is generally delineated by simple striping, two sets of double-yellow lines about three feet apart. Enforcement is done by highway patrol and very substantial fines for violators. Access restrictions are also employed on a number of similar HOV lane treatments in Washington D.C., Minneapolis, Atlanta, Dallas, Houston and Denver.

Pricing (HOT lanes, in this instance) offers a third strategy to manage lane demand. This strategy has multiple objectives. Pricing to separate 2-person and 3+ occupancy HOV users is applied to manage HOV demand on two HOV lane segments in Houston; 3+ vehicles go for free, 2-person vehicles pay a toll, SOVs are excluded. Pricing as a means of managing demand among a wider number of user groups is practiced on SR 91 in Orange County and I-15 in San Diego County. Variable tolling offers a means of managing demand to stay within the lane's capacity. Prices may be varied throughout the peak period to adjust to recurring demand (as in SR 91), or to changing roadway conditions (dynamic pricing, as in I-15).

Efficiency Under the HOV-only vs. HOT Management Strategy

When applying all three of these strategies in combination – HOVs ride for free, limited access locations, and variable pricing for non-HOVs--, the efficiency advantages over a pure HOV lane are readily apparent. Recognizing and applying this larger array of traffic management tools could enhance the value and attractiveness of HOV lane strategies. Both of the California time-variable toll projects, SR 91 and I-15, employ a combined strategy of user benefits and assured level of service to HOVs, while also limiting access and pricing residual lane capacity for SOVs.
The characteristics of pricing as a management tool include:

- An assured level of service is provided to HOVs. Access restrictions enhance the entire freeway throughput and its performance, and pricing permits modest adjustments to demand management strategy that are not possible when applying user or access restrictions alone.

- Revenue generation. As a matter of local policy, any revenue generated via pricing can also be used to promote HOVs through added transit services, as currently done in San Diego's I-15, and additional enforcement presence. Revenues could also be used to build and extend the HOV lanes.

Equity

When pricing is applied to allow single-occupant vehicles to share the HOV roadway, concerns about equity are frequently raised. With tolling, users whose delay is the most costly and who value their time more highly are permitted the option of traveling in the less congested, more reliable HOV/HOT lane. This can significantly improve their travel times. These users could include not only high-time-value SOVs, but potentially (under the 3+ carpool option) 2-person carpools whose occupants would split the cost of the toll.

The SR 91 and I-15 experience has demonstrated that it is <u>not only high income individuals</u> who have high values of time. Often lower-income individuals have high values of time on some occasions, because, for example, they lack flexibility in job-arrival time or childcare pickup time. From the equity standpoint, a case can be made that those with low-income are most harmed by not having the choice to bypass congestion on those occasions when being late entails a high penalty. Survey results on existing HOT lanes indicate that having the option to pay a toll and be assured reliable time-savings can be valuable to persons across the income spectrum, though higher-income people will generally have a propensity to use HOT lanes more frequently than do lower-income people.

Another way to view equity is to compare methods of road financing and analyze how a HOT lane system compares with other financing sources. A HOT lane toll is paid only by users who gain a benefit; it is paid only by choice, as all users have an adjacent free mixed-flow option; most toll-payers are employed persons seeking to save valuable time, not retired or low-income unemployed.

The major alternative sources of road financing in California are the sales tax and per gallon gasoline tax. Sales taxes are often viewed as relatively regressive, taking a disproportionately large share of the income of lower-income families, and thus may be more inequitable than tolls from the income distribution standpoint. Furthermore, sales taxes are not a road "user fee" in any sense, but paid by all consumers on all taxable products. Gasoline taxes are roughly proportional to auto usage – though varying greatly by gas mileage of different vehicles. However, the gas can be consumed at any time of day or any facility used, so there is no necessary relationship between the burden placed on the road system by the driver and the amount of tax paid. This may be viewed as inequitable to other users. Thus, a case can be made that a toll paid directly by the user in exchange for a benefit is more equitable than either sales taxes or gasoline taxes.

Impacts on HOVs

The time savings benefit provided to any HOV or dedicated lane user are the same, and if not managed to protect these benefits, all lose. Thus, a fundamental requirement for any dedicated lane is preservation of an acceptable service level. The available and finite capacity offered to SOVs can be managed—through pricing—so that the level of service will not be impaired, nor will there be a significant shift from HOVs to SOV toll-payers. This is because the price can always be adjusted to regulate the number of toll-paying users. When demand becomes too high, the price goes up; when demand falls, the price goes down. Pricing can be employed by freeway managers only when there is excess capacity to sell, and there is a willingness to pay tolls only when there is available capacity to sell, i.e., only when the toll payer is offered improved travel time.

When HOV lane capacity is largely consumed by HOVs, lane management will necessarily curtail access to toll-paying users. While the generally accepted capacity of a mixed-flow lane may be around 2,000 vehicles before gridlock may occur, the maximum recommended usage for an HOV or HOT lane is only 1600-1700 before lane performance may be impacted. If the lane is overloaded, it can no longer fulfill its primary function—providing speedy and reliable service as compared to the adjacent mixed-flow lanes.

Overloading is a risk with HOV-only lanes with the 2+ carpool definition currently in effect in most northern California locations. If an HOV lane becomes overcrowded with 2+ carpools, there is no way to adjust usage, except to make the difficult policy decision to increase the carpool definition to 3+ occupancy, a step which has never yet been taken in northern California. Instead, the carpool lane performance just degrades until carpool formation is discouraged, due to lack of benefits to the users. However, if and when the occupancy requirement is changed from 2+ to 3+, it is likely that there would be an abrupt decline in carpool usage of HOV lanes, because many drivers able to form 2-person carpools will be unable to form 3-person carpools. Then, the HOV-lane <u>overutilization</u> problem would immediately be replaced by a severe <u>underutilization</u> problem. This is precisely what occurred on the Interstate 10 Katy Freeway in Houston, when the overused 2+ HOV lane was changed to 3+, and three-quarters of the users went away. Eventually, Houston instituted a pricing system to allow 2-person carpools to buy back into the lane.

One additional impact on HOVs has been hypothesized: a reduction in the number of carpools would occur due to the availability of the toll-paying option for solo drivers. While this seems a reasonable hypothesis, the experience in San Diego's I-15 HOT lanes does not bear this out. In October 1996 (before HOT lanes were instituted) there were 7,700 carpools per day. As of May 2003, there were 16,800 carpools per day (118% increase). No survey data is available to explain this increase, but local managers of the program offer several explanations: (1) the perception of higher value in HOV/HOT lanes, which people can obtain for free by carpooling and (2) greater likelihood to form a carpool in the first place, because increased reliability in trip planning makes it more attractive to form carpools, with the knowledge that a time-saving toll option is also available on those days when a person is unable to carpool. In addition, opinion surveys of users have indicated that support has grown for the HOT lane concept since it has been in operation.[16]

Impacts to the HOV Lane Design

This I-680 study and others performed on freeway corridors in California document that the primary design changes associated with employing these other lane management strategies include limiting access to designated locations and adding electronic equipment and enforcement capability to the roadway. Both of these design provisions have minimal impact to the Caltrans standard carpool lane design criteria. Similar design enhancements have been previously demonstrated on SR 91 and I-15 in California.

Access restrictions can be provided through the use of designated and striped buffer areas, and may also be delineated with the use of traffic channelizers, such as plastic pylons. The added cost for channelizers can be offset by toll revenues. Pricing equipment, such as toll readers and message signs, may be limited to a single toll zone or multiple zones depending on the number of intermediate access points. These zones do not require major roadway widening or barrier separation from adjacent traffic lanes. They are ideally sited where HOV enforcement areas could otherwise be installed.

In summary, all of the three dedicated lane strategies— user restrictions, access restrictions and pricing — have the potential to enhance total corridor mobility and efficiency, and the means to manage traffic.

Institutional Arrangements

Interstate 680 is currently a state-owned and operated facility. Aside from the state-owned toll bridges, the state currently operates no other toll facilities. The segment under consideration for the HOT lanes is almost entirely in Alameda County, but also has a small portion in Santa Clara County. In addition, congestion on I-680 significantly impacts Contra Costa and San Joaquin County residents, businesses and organizations. Because of the unique nature of this project, an I-680 HOT lane will require some new institutional arrangements.

There will be a need for an entity, existing or new, to manage, operate and maintain the HOT lanes, administer the finances and determine the use of revenues. Because the financial projections indicate that HOT lanes would defray all of the facility's operational costs and yield net revenues, it should be possible to attract the private sector to manage and/or operate the system. The following are some potential institutional arrangements for the I-680 HOT lanes project.

Public Finance, Development, Ownership and Operation of HOV/HOT Lanes

This option is closest to the current institutional arrangements. A public agency, or consortium of public agencies, would develop, finance, own and operate the HOT lanes. First call on the funds would be for facility maintenance and operations. The net toll revenues would be available for a variety of purposes. This study recommends that the use of the revenues be explicitly and permanently limited to transportation purposes on the I-680 corridor, such as further capital improvements and transit services.

[16] *I-15 Congestion Pricing Project Monitoring and Evaluation Services, Phase II Year Three Attitudinal Panel Survey*, San Diego State University, February 2001

In order to gain and keep public acceptance for HOT lanes, it will be essential to assure users that the revenues not be diverted for purposes other than transportation in the corridor.

A variety of institutional options are available for public ownership and operation:

- Caltrans
- A regional organization, such as the Metropolitan Transportation Commission or Bay Area Toll Authority
- Alameda County agency, such as the Congestion Management Agency or Alameda County Transportation Improvement Authority
- A new entity formed by joint powers agreement among agencies from several counties, cities and other institutional participants

The allocation of decision-making authority, risks, and permissible or mandated uses of funding would need to be spelled out in a charter approved by the public agency participants.

<u>Private Sector Participation</u>

There are a number of potential ownership and operating relationships that can be used to engage the private sector. The pattern of ownership greatly affects risk-sharing, financing terms, and access to types of financial instruments, including:

- *Build-Transfer-Operate (BTO).* This scenario would be similar to the SR 91 toll lanes in Orange County. The SR 91 facility was built by a limited partnership called the California Private Transportation Company (CPTC). CPTC was responsible for developing, financing and building the SR 91 toll lanes in the median of SR 91 under a franchise agreement awarded by Caltrans. CPTC transferred ownership to Caltrans when construction was completed, and Caltrans then leased the facility back to CPTC for 35 years. During this period, CPTC was allowed to maintain toll rates to achieve the negotiated maximum return on investment; any revenues in excess of this amount must be used to accelerate debt payment or be deposited in the State Highway Account. In 2003, after 8 years of private operation under this agreement, Orange County Transportation Authority decided to purchase the facility outright from CPTC, but maintained a contractual agreement for CPTC to continue managing the toll facility. Assuming that the public sector will build the basic additional HOV lanes on I-680, what could be "built" by the private sector would be the toll collection and any other infrastructure to make a conventional HOV lane into a HOT lane.

- *Operation and Maintenance Agreements.* A contract is let to a private entity to manage the facility entirely or in part. For example, the public entity owning the facility could seek a private contractor to maintain toll collection equipment, manage accounts, collect tolls, market the HOT lanes, etc. The contractual arrangement could be in the form of a lease, payment for services, a percentage of revenues, or some combination.

As a practical matter, a wide variety of institutional arrangements for I-680 is possible. The arrangement will be determined by several public agency participants and how they wish to resolve issues of control, risk and benefits. Reaching an agreement is likely to be a complex process.

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CHAPTER 12:
EVALUATING THE ALTERNATIVES

This chapter applies the evaluation criteria set out in Chapter 6 to alternatives that were analyzed in detail Chapters 7, 8, and 9 (travel forecasting, financial feasibility, and operations) in this study. Early in the study, it was determined that detailed analysis of revenue generation and operations would be done only on the non-reversible 8-lane options under Alternative A (described in Chapter 5). The reasons were twofold:

(1) This alternative was deemed by Caltrans to be the most likely near-term build alternative to be implemented. It meets the near-term need with the lowest capital and operating cost, but does not preclude the possibility of ultimately moving to reversible or 9-lane options.

(2) It became apparent early in the study that several important policy options under Alternative A, including different intermediate access and carpool definitions, would be considered. The study scope for travel and financial forecasting was able to accommodate a limited number of options, and the different options for limited access and for carpool policies were viewed as the most in need of detailed investigation. Thus, all of the detailed analysis was done for the 8-lane, non-reversible options under Alternative A.

This does not imply that the reversible lane Alternatives B, C, D and E are excluded from consideration by Caltrans or definitively rejected as possibilities. Nor does it imply that a HOT lane could not be feasible under the reversible lane scenarios. In fact, if vehicle volumes grow markedly higher than forecast in the peak directions and the 2+ carpool definition is maintained no matter what its impact on HOV lane functioning, then reversible lanes, or adding a ninth lane in the median, may be the only way to maintain satisfactory service on the HOV and/or HOT lanes. In that case, an additional financial and operational feasibility analysis would have to be completed.

Table 12-1 applies the evaluation criteria to the HOV-only scenarios and to the HOT lane options. The HOT lane options are: A-3, no intermediate access, and either 2+ or 3+ carpool definition; and A-4, one intermediate access, and either 2+ or 3+ carpool definitions. In each case, the HOT lane alternative is compared to the HOV-only base case. For the purpose of this comparison, the conventional, unlimited access HOV is assumed to be in place, and its physical, financial, and operational characteristics are what the HOT lane alternatives are evaluated against. The qualitative 7-point scale is from triple plus (+++) at best, through triple minus (---) at worst, with 0 being essentially equivalent to HOV-only. A narrative explanation of each criterion rating follows the table.

Table 12-1: Evaluation of Alternatives

Criterion	Alternative A-3 2+	Alternative A-3 3+	Alternative A-4 2+	Alternative A-4 3+
Corridor travel impacts	0	0	0	0
Operational impacts	-	-	-	-
Geometric	0	0	0	0
Safety	0	0	0	0
Tolling & Enforcement	- +++	- +++	- ++	- ++
Travel Options	++	++	+++	+++
Capital Cost	-	-	--	--
Revenue Generation	++	+++	++	+++
Net Operational Revenue	++	+++	++	+++
Environmental Impact	0	0	0	0
Equity	0	0	0	0
Transit impact	+	++	+	++

Corridor Travel Impacts: The average speed data are mixed, with HOT alternatives' southbound AM average corridor speeds lower in 2000, but approximately the same in 2025. Northbound PM speeds are slightly lower for HOT alternatives in 2000, but higher in 2025 in most cases. In all cases, however, the speeds in the both the HOV-only and HOT alternatives are very high (between 62.1 and 65 mph) and virtually identical among alternatives; this demonstrates that none of the alternatives impairs HOV lane operations. Delays, as measured by vehicle-hours-traveled, were slightly higher for HOT alternatives southbound AM in 2000, and approximately the same in 2025. On the other hand, northbound delays for HOT alternatives were lower in most 2025 scenarios and split (two higher, two lower) in 2000. Person-throughput measures show a similar trend: HOV-only is higher southbound, but several HOT alternatives are higher northbound. In all cases, the addition of the mitigation measures described in this report substantially increases both average speeds and person-throughput in all HOV-only and HOT scenarios. The conclusion is that the balance of positive and negative impacts among the alternatives on various performance measures is roughly equal, and that all perform comparably well, especially when compared to the No Build case.

Operational Impacts: All HOT alternatives have a modest negative impact on operations, as compared to a conventional continuous access HOV lane, but that impact can be mitigated by improvements that restore capacity. The impact results from two factors: (1) limited access requires all vehicles wishing to use the HOV/HOT lane to enter and exit the lane at only one or two locations, and (2) more vehicles will be using the HOV/HOT lane than would use an HOV-only lane. This may cause queues to form at those limited ingress/egress locations. By restoring lost capacity through a short transition lane in the vicinity of those locations, the impact largely disappears. It should also be noted, however, that continuous access brings operational issues of its own, i.e., the weaving/churning that occurs throughout the length of the HOV lane as vehicles move in and out of the lane at any location. The operational analysis shows that the transition lanes for mitigating this effect at both ends of the project are equally applicable to any HOV-only project.

Geometric: There is essentially no difference in the geometry and configuration of the HOV-only and HOT lane alternatives. Curves and shoulder widths are approximately the same. Enforcement areas necessary to HOV lanes are available for HOT lane enforcement as well, although the locations of such enforcement areas might be modified in order to make them consistent with the location of toll readers.

Safety: There is essentially no difference in the safety factor that can be demonstrated between HOV-only and HOT. A case could be made that HOT configurations might be safer, because they limit weaving throughout most of the lane's length and provide more of a buffer between the HOV/HOT lane and adjacent mixed-flow lane. However, there is not sufficient empirical data to justify that supposition.

Tolling and Enforcement: This is the most difficult criterion to apply, because there are definite pros and cons to HOT lanes in this criterion – hence, both minus and plus ratings in the Table 12-1 matrix. All HOT alternatives are unquestionably more complicated to enforce than is a conventional HOV-only lane, because there is an additional potential violation – the non-tollpaying SOV user of the HOV lane. The enforcement officer, or video monitoring, must look for both the number of passengers in a vehicle and whether a toll has been paid. The toll payment is shown by the toll reader and indicated by some kind of visual illumination on the overhead toll-reader. Thus, the user has two, rather than one, way to be in the lane legally, and the officer or video monitor must ascertain that neither applies before identifying a violation.

On the other hand, the limited access aspect of the HOT alternatives eases enforcement in another way, because it creates one clear, undisputed violation that can be enforced. If a vehicle crosses the striped barrier at any point except the designated locations, it is a clear violation, regardless whether the vehicle is an SOV or HOV. Furthermore, the availability of an option to pay a toll of a few dollars and benefit by substantial time savings, versus the risk of a fine of nearly $300 or more, greatly reduces the incentive to violate an HOV-only lane. This should have the effect of reducing the violation rate from what is would otherwise be. Experience bears this out. Violation rates at the SR 91 and I-15 HOT lane facilities are in the 1.5% to 2.5% range, considerably below the rates observed on conventional HOV lanes. Finally, the enhanced Highway Patrol enforcement presence that would be part of this project, paid for by toll revenues, provides a further significant deterrent to violation.

Travel Options: All HOT lane alternatives have a clear advantage over HOV-only, because they provide the freeway user a new option they never could have otherwise – the ability to pay a toll in exchange for substantial time savings and reliability on those occasions when this is most valuable to them. The A-4 Alternative, with intermediate access, provides somewhat more options because of greater ingress/egress flexibility.

Capital Cost: All HOT lane alternatives incur a capital cost not associated with HOV-only lanes, namely the cost of the tolling system. This cost is estimated to be in the neighborhood of $3.2 million. The intermediate access Alternative A-4 incurs an additional cost of $4.6 million for a short transition lane restoring capacity in order to accommodate more easily the traffic entering and exiting the intermediate access location.

Revenue Generation: The HOV-only project generates no revenue. The HOT alternatives generate between $6.3 and $14.7 million in the first year, and between $12.3 and $31.9 million by the twentieth year and continue to generate revenue for the full life of the facility.

Net Operational Revenue: The HOV-only project generates no net revenue. HOT lanes generate a positive revenue stream from its first year of operation. Over a 20-year period (assuming a conservative 4% real discount rate) HOT alternatives generate between $83 million and $228 million. The HOT alternatives A-3 and A-4 with the 3+ carpool policy perform much better financially than the 2+ alternatives, because they provide more capacity to sell to tollpaying customers. Alternative A-3 (no intermediate access) performs somewhat better financially than does Alternative A-4, with intermediate access, presumably because all users in A-3 are paying for a longer distance, while some in A-4 are paying for only one segment. The HOT lane revenue can be used to pay for corridor improvements such as partial construction cost for the freeway widening itself or enhanced transit services on the corridor.

Environmental Impact: There is no appreciable, known difference in environmental impact between HOV-only and HOT alternatives, or among HOT alternatives. The air quality and fuel efficiency analyses (not part of this study) could conceivably uncover slight variations. It is possible that the availability of HOT lane options could reduce HOV formation or, conversely, that better HOT/HOV lane enforcement would lead to better HOV lane performance and therefore induce more carpool formation. At this level of inquiry, it appears unlikely that there would be a significant difference in environmental impact among the various HOT lane alternatives.

Equity: Because equity can be defined in several ways, this criterion is difficult to evaluate. From the income distribution standpoint, more affluent users could afford to pay a toll to bypass congestion, while less affluent users may be less able to afford it; this might be viewed as inequitable. From the standpoint of benefit/cost ratio, users paying for a benefit accruing to them is equitable, especially if revenues are used to improve transit service on the corridor. Better transit service makes travel more accessible and affordable to others, including those with lower incomes lacking access to an automobile. This analysis finds that the equity issues are offsetting and no significant difference among alternatives is found.

Transit Impact: HOT alternatives have the potential to be superior to HOV-only. They provide substantial revenues for potential use in improving corridor transit, both bus on the freeway and even ACE train service. The HOT alternatives with 3+ carpool policies are more beneficial for transit, because they offer a larger pool of potential transit customers – former 2-person carpoolers. The only potential negative impact on transit might be reduced speeds for buses, in the event that too many HOT vehicles are permitted on the HOV/HOT lane. However, that result can be easily avoided by adjusting tolls upward to reduce HOT vehicles usage of the lane.

CHAPTER 13: CONCLUSIONS

1. Adequate capacity exists on I-680 to sustain HOT lanes as a viable alternative.

Travel forecasting indicates that substantial capacity will be available to permit introduction of a HOT lane concept. Year 2000 forecasts show a great deal of excess capacity under all HOV/HOT scenarios, and year 2025 forecasts show some available capacity under most scenarios. The most problematic scenario is with only one segment of Alternative A-4 (intermediate access) under the HOV2+ policy in year 2025. Obviously, a change to the HOV3+ policy at any time would create much more excess capacity and would significantly increase the attractiveness of buying into the lane, resulting in a greater number of potential toll-payers.

Nevertheless, travel forecasting is an inexact science and the projections in this study could be proven inaccurate by experience and unforeseen developments. In the event that the travel forecasts prove to be too low for HOVs and/or for HOT vehicles, there are several policy responses available. First, the toll level can be raised until it reduces the number of toll-payers to a manageable number. Second, a move from a 2+ to a 3+ HOV policy could be considered. Third, the HOT option can be suspended until traffic conditions warrant its resumption. Because the capital investment in the HOT system, primarily in toll collection equipment that could remain in place, is relatively quite small in comparison to the entire widening project, the at-risk investment of trying a HOT lane concept would be relatively modest.

2. I-680 HOT lanes are financially feasible.

HOT lanes elsewhere in California have demonstrated that people are willing to pay tolls to save time instead of being forced to use the adjacent toll-free but congested highway lanes. Revenue and cost analysis for this segment of I-680 indicates that a HOT lane system on I-680 would generate substantial positive cash flow over the life of the facility. To adopt a HOT lane system would entail an investment of approximately $3.24 million in capital for toll collection/enforcement equipment and $1.02 million in annual operating costs. Further widening (beyond that required by the conventional HOV lane) at an intermediate access location, if deemed necessary, would entail approximately $4.6 million in additional costs. Because the estimated annual net revenues range from $6.3 to $14.7 million in Year 1 of operation and $12.3 to $31.9 million by Year 20 of the program, the HOT lanes are financially advantageous. The prospective positive cash flow would also permit bonding to accelerate this or other I-680 corridor improvement projects, attract private investment (if desired), and pay for other services, such as enhanced transit services.

3. I-680 HOT lanes are operationally feasible.

The combined HOV/HOT lanes can be operated in a manner that maintains smooth and congestion-free traffic flow on the HOV/HOT lanes without unduly impairing the functioning of the adjacent mixed-flow lanes. Mitigations that provide additional through-lane or transition lane capacity at the ingress and egress locations for the HOV/HOT lanes largely resolve the queuing problems that might otherwise occur as a result of large number of vehicles getting on or off at the same location.

4. HOT lanes have no performance impact on HOV lanes, but some positive and negative impacts on the performance of adjacent mixed-flow lanes.

The performance measures applied in the operational analysis shows mixed performance results as compared to HOV-only lanes, some positive and some negative. There is only a negligible impact on the travel speeds on the HOV lanes caused by the addition of the HOT vehicles. However, when compared to HOV-only alternative, HOT alternatives have a negative impact on total corridor southbound AM travel speeds in the mixed-flow lanes in year 2000, though a negligible impact in 2025. They have a slightly negative impact northbound PM in year 2000, and a positive impact in 2025.

The negative impacts are primarily due to the limited access feature of the proposal, not the pricing component, Some vehicles that would otherwise use the HOV-only continuous access lane will remain in the mixed-flow lanes instead of using the HOV lanes, due to their need to get on or off at locations other than those permitted in the limited access configuration. While this problem could be mitigated by adding more intermediate access locations, that solution might also add to the cost of the project.

The major positive operational impact of limited access is that it would substantially reduce weaving between HOV and mixed flow lanes and therefore increase driver certainty about when and where to expect other vehicles to enter or exit the lanes.

5. HOT lanes are compatible with HOV lane operations...with a caveat.

Lanes that are jointly used as HOV and HOT users are compatible, in that neither interferes with the operation of the other. HOT lane tolls can be adjusted upward or downward as traffic conditions warrant to assure a high level of service in the HOV/HOT lane. The HOT lane gives drivers the option to receive the benefit of better service and reliability on those occasions when they cannot form a carpool.

Once again, however, it is the limited access feature of the proposed HOT lane that creates a complication for the HOV user. All viable HOT lane alternatives virtually require limited, rather than continuous, access in order to assure adequate enforcement and toll collection. But the consequence is that the HOV user is also restricted in locations to enter or exit the HOV lanes. While the limited access feature brings benefits – generally better speeds and reliability --, this reduction of choice for the HOV user may be seen as a detriment. This problem could be addressed by adding several more intermediate access locations on the corridor.

6. Enforcement can be maintained at a reasonably high level.

The proposal for I-680 would be an innovation in HOT lanes, because it proposes to keep HOT vehicles separated from the mixed-flow lanes only by a highly visible, but non-physical, barrier (a buffer of 2-4 feet, striping and signage). This places more reliance on enhanced highway patrol presence, video surveillance, and to some degree, the "honor system." HOT lanes in Orange County and San Diego show very low violation rates in the 2% range, but they also have physical barriers separating them from mixed-flow lanes. The I-680 lane separation proposal is much less expensive and more flexible than a physical barrier separation, and that is why it is recommended here. However, it would test enforcement effectiveness under different circumstances than have been tried elsewhere.

Nevertheless, it is likely that enforcement effectiveness and violation rates on I-680 would be much improved, as compared to what they would be with the HOV continuous access system now common in the Bay Area. This is so for several reasons: (1) highway patrol presence would be greatly enhanced, paid for by the revenues generated by the HOT lanes; (2) video surveillance will provide for a deterrent and potential detection of violators; (3) limited access makes it easier to spot a violation, because any vehicle making a lane change outside of authorized locations is a clear violation, whether or not a toll is paid; (4) providing the option for SOVs to pay a small toll in order to avoid the risk of a very large fine reduces the temptation to violate the HOV lane, if saving time is highly valuable to the driver.

An additional advantage of the stepped-up enforcement that accompanies HOT lanes is the effective increase in the capacity of the HOV lanes. Assuming that the current average violation rate on Bay Area HOV lanes is in the 5-10% range and that a robust enforcement regime can reduce that to the 2-3% range, that is the equivalent of adding 2-7% more capacity to the lane for legitimate HOVs and HOT toll-payers. This capacity increase is gained through better management and without having to incur the substantial cost of adding physical capacity in the form of more freeway lanes.

7. HOT lanes can be implemented with flexibility.

The HOT lanes proposed for I-680 could be implemented and adjusted in several ways over time, which increases their attractiveness as an experiment. First, limited access could be applied with none, one, or more intermediate access locations. The locations could be changed to fit observed or new traffic conditions. Those adjustments could be made in many cases by the simple process of re-striping, including shortening or lengthening the ingress/egress sections or moving them slightly to the north or south. When adding intermediate access, more capital intensive solutions could be considered. For example, an additional intermediate access might require an additional transition lane for a short distance. If necessary, these adjustments can generally be made within the existing freeway footprint.

Second, the number, location, and functions of signage and video surveillance can be modified as needed. If particular "hot spots" are found where driver confusion or high violation rates are prevalent, this aspect of the system can be changed quickly and inexpensively.

Third, the tolls themselves are subject to modification. Despite the best efforts of travel and economic modeling, it is entirely possible that some of the initial toll levels will either be too low or too high. After a period of observation, the prices or hours can be adjusted to optimize the efficiency of the freeway management, using existing capacity to the maximum extent while generating revenues. Just as the case with the SR 91 and I-15, tolls will be adjusted periodically to reflect changing conditions.

Finally, in the event that the HOT system proves to be unworkable or unacceptable for some reason, it can be suspended at any time, with minimal loss of investment. On the other hand, if it proves successful, it could serve as a model that is replicable on other HOV lane facilities, suitably tailored to the circumstances of those facilities.

8. Implementation faces major challenges.

Implementing HOT lanes on I-680 faces several major challenges. As noted in Chapter 3, many road pricing concepts have been studied, but few have been chosen. A HOT lane system on I-680 must satisfactorily address these key issues before it can be implemented:

- Local agency consensus. Before moving forward, local decision-makers in Alameda, Contra Costa and Santa Clara counties, and the Metropolitan Transportation Commission will have to decide that this is an experiment worth trying.
- Caltrans acceptance. Because Caltrans is the operator of the freeway, it must be comfortable that a HOT lane concept is operationally feasible on this segment of I-680.
- State authorizing legislation. The state legislature must authorize the use of HOT lanes on this specific segment of freeway; state legislation was required for both I-15 and SR 91 HOT lanes and will also be required for I-680.
- Congressional support. As a practical matter in the current budget circumstances, Congressional support for federal funding and Federal Highway Administration approval of this proposal is likely to be needed.
- Acceptance of limited access HOV lanes. The region's decision-makers and the general public must determine that limited access HOV lanes, even though they are already the rule in Southern California, will be acceptable and beneficial in at least one Bay Area location.
- Equity concerns. Decision-makers and general public must determine that a HOT lane in this location is equitable and beneficial to the public, because it provides an option for users, better use of the freeway capacity, benefits for transit service, etc.
- Institutional and jurisdictional arrangements. There are myriad ways in which a HOT lane system could be financed and operated -- any number of existing agencies, a joint powers agreement, private investment and/or management, etc. These issues must be settled as part of the implementation process. Determining issues of who assumes financial risks and rewards will be paramount and may not easy to negotiate.
- Use of the revenues. Assuming that the positive revenues projected by the analysis do materialize, the question of how the revenues are to be used must be addressed. In view of the current serious budget problems faced by transportation agencies, there could be significant competition for this new source of revenue.

- Unfamiliarity. A major challenge is the fact that a HOT lane with variable pricing is something new for a region unfamiliar with road pricing of any kind (except fixed-toll bridge crossings). A HOT lane application on I-680 would be the first of its kind in the San Francisco Bay Area and one among few in the United States. Despite the fact that several HOT lane projects in Southern California have been in successful operation for years, there is no substitute for personal experience. The impetus for considering I-680 as a HOT lane project at this time is a combination of serious traffic congestion levels, the need to utilize planned freeway capacity efficiently, and a potential new revenue source in an era of declining transportation finances. If this proposal is to move forward, it will be as a result of this combination of factors.

Appendix A

Existing Conditions Report

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Value Pricing Feasibility Study
For I-680 Corridors Project
Task 3: Existing Conditions

In Alameda and Santa Clara Counties

May 14, 2002

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

INTRODUCTION

Peak period traffic volumes have increased dramatically in the I-680 Corridor to the extent that in the Fall of 1995, formerly free-flowing traffic became congested over a more than ten mile section from before 6 a.m. through 9 a.m. on weekdays. The corridor quickly became the second, then the first-most congested in the entire Bay Area, surpassing even the Bay Bridge and I-80 in 1999 and 2000. The main cause is the strong job market in southern Alameda County and Santa Clara County (Silicon Valley) coupled with a lack of available housing. Employees taking jobs in Silicon Valley live in southern and eastern Contra Costa County, eastern Alameda County and the San Joaquin Valley. The I-680 Corridor is the only major route that links the jobs in Silicon Valley with employees living in these outlying areas.

As part of the Value Pricing Feasibility Study for the I-680 Corridors Project, Task 3 presents a description of existing conditions. The study area extends along I-680 from I-580 to the Montague Expressway, and also includes I-880 in Fremont and Milpitas, I-580 east of I-680, and SR 84 between I-580 and I-680. All these facilities act as one system connecting the jobs of Silicon Valley with housing in the outlying areas of Contra Costa and Alameda Counties, and the San Joaquin Valley.

There are several other studies being conducted at the same time that influence the findings in this study. The most important of these is the feasibility study for the extension of BART to San Jose. Another important study is the I-680/I-880 Cross-Connector Study being conducted by the Valley Transportation Authority.

This document examines existing traffic volumes and patterns, vehicle occupancy, travel times and speeds, and trip origins and destinations.

FIGURE 1: VICINITY MAP

Figure 2 illustrates the number of lanes on the study routes. The following discussion highlights other physical characteristics of the study routes.

Interstate 680 is a north-south highway extending from I-80 near Fairfield to US 101 in San Jose. Within the study area, it traverses Milpitas, Fremont, Sunol and Pleasanton. I-680 travels through mountainous terrain between Mission Boulevard (SR 238) in Fremont to Bernal Avenue in Pleasanton. Figure A-1 in Appendix A illustrates interchange geometry on I-680 throughout the study area. The freeway generally has three through lanes in each direction from Calaveras (SR 237) to I-580. There is a truck climbing lane southbound over the Sunol Grade from Andrade Road to just past the Sunol Grade. One left shoulder HOV lane in either direction is under construction from Calaveras in Milpitas to SR 84 near Sunol. The construction of these HOV lanes is the result of an earlier study that justified the lanes on the basis of congestion reduction and promotion of transit and ride sharing.

Interstate 580 is an east-west interstate highway extending between I-5 in San Joaquin County and US 101 in San Rafael. It is a major link between the farmlands of the Central Valley and the Port of Oakland. In the study area, I-580 traverses Livermore, Pleasanton and Dublin. Mostly undeveloped lands are adjacent to both sides of I-580 between SR 84 and Tassajara Road, with major new development now occurring on the north side of I-580 between Tassajara Road and Dougherty/ Hopyard Road in Dublin. I-580 generally has four through lanes in each direction within the study area with a 30 foot median. BART runs in the median through the study area, with its easternmost Alameda County station located between Hopyard Road and Hacienda Drive. Shoulders on the right are generally 12 feet wide. Figure A-2 in Appendix A illustrates interchange geometry on I-580 throughout the study area.

Interstate 880 is a north-south interstate highway that traverses Fremont and Milpitas in the study area. Shoulder widths generally vary from eight to twelve feet. I-880 has been widened with both mixed flow and HOV lanes in the study area in recent years. Currently, a major interchange reconfiguration project is underway at SR 237 and I-880 including direct connector HOV lanes between SR 237 to the west and I-880 to the north.

State Route 84 travels in a southwest-northeast direction through the City of Livermore as well as unincorporated areas of Alameda County. It provides a connection between I-680 and I-580 via interchanges in Sunol and Livermore. The portion immediately east of I-680 is relatively flat and straight. Between this portion and a point south of the Livermore city boundary, SR 84 is a two-lane, hilly and winding rural highway with narrow shoulders in many locations and restricted design speed. The adjacent areas are relatively undeveloped and access points are few. There are virtually no intersecting roads except private driveways that serve as access to the nuclear laboratory, access to the San Antonio Reservoir, and private homes.

Through the City of Livermore, SR 84 runs along existing arterial streets: Vallecitos Road, Holmes Street, and First Street. In addition to providing state highway routing for through traffic, the existing route provides the primary local access to adjacent developed areas. A major portion of this route serves local residential traffic needs. The northern portion serves the downtown both as a major arterial to south Livermore and as a southbound route out of town to I-680, Fremont and the South Bay.

FIGURE 2: NUMBER OF LANES ON STUDY AREA FACILITIES

Construction is under way to relocate SR 84 from its present route in Livermore to Isabel several miles to the west.

State Route 262 (Mission Boulevard) is an east-west arterial route between I-680 and I-880 in Fremont. There are two signalized intersections at Mohave Drive and Warm Springs Boulevard along its one-mile length. A railroad undercrossing exists between Warm Springs Boulevard and I-880. There are generally three through lanes in each direction, excepting that only two lanes extend onto I-880 or under I-680, where the right lane is added from the freeway off ramps or dropped at the freeway on ramps.

State Route 237/Calaveras Boulevard is a six-lane east-west arterial between I-880 and I-680 in the City of Milpitas. There are six signalized intersections within this segment, which is generally fronted by commercial and retail uses on both sides throughout the study area. SR 237 becomes a six-lane freeway west of I-880.

Montague Expressway is a six-lane east-west expressway in southern Milpitas and northern San Jose. Between I-680 and I-880 there are five signalized intersections: Pectin Court, Milpitas Boulevard, Capitol Avenue/Great Mall Parkway, McCandless/Trade Zone Boulevard, and Main Street/Old Oakland Road. From 6 a.m. to 9 a.m., the outside lane in the westbound direction from Pecten Court to Main Street/Old Oakland Road serves as an HOV lane. From 3 p.m. to 7 p.m. the outside lane in the esatbound direction from Main Street/Old Oakland Road to Milpitas Boulevard serves as an HOV lane. The HOV lanes are discontinuous at the I-880 interchange. In the non-peak direction, and during off-peak times, the HOV lanes are available for mixed-flow traffic. The Santa Clara Roads and Airports Department estimates current HOV lane usage at approximately 16% of total peak hour through movement volume in each direction. Both sides of the expressway are fronted by commercial uses.

Automall Parkway is an east-west arterial route in the City of Fremont. Between I-680 and I-880, there are four signalized intersections: the I-680 southbound off ramp, Osgood Road, Fremont Boulevard and Grimmer Boulevard. This route generally provides four travel lanes and has bicycle lanes in each direction. A railroad overcrossing exists between Osgood Road and Fremont Boulevard. There is a raised concrete median between I-680 and Fremont Boulevard. From Fremont Boulevard to Grimmer Boulevard, there is a 100 foot-wide median with three steel towers supporting overhead power lines. Residential and commercial uses front along the north side of Automall Parkway. Primarily undeveloped lands are adjacent to the south side of the roadway.

Sunol Boulevard/First Street/Stanley Boulevard are connected major southwest-northeast arterials in the cities of Pleasanton and Livermore that, in addition to local traffic, serve regional traffic between I-580 and I-680. According to the City of Pleasanton *Arterial Cut-Through Traffic Study* (March 1998), while most of the traffic external to Pleasanton probably originates in Livermore, some traffic from places such as Tracy or Brentwood may also use this route to avoid congestion on SR 84 as well as I-580 and I-680, especially during significant congestion during incidents and Friday evenings.

At the southwestern end of the corridor, Sunol Boulevard has a 12-foot wide painted median between I-680 and Bernal Avenue. Residential uses are located east of Sunol Boulevard; commercial uses are located on both the east and west sides.

In Pleasanton, First Street is the intermediate link of the corridor between Sunol Boulevard (at Bernal Avenue) and Stanley Boulevard. It is a two-lane arterial through downtown Pleasanton with many local intersections. Turn pockets and center two-way left turn lanes alternatively provide for left turns. At its northeastern end is a two-lane bridge spanning the Arroyo Del Valle; this bridge will soon be widened to four lanes.

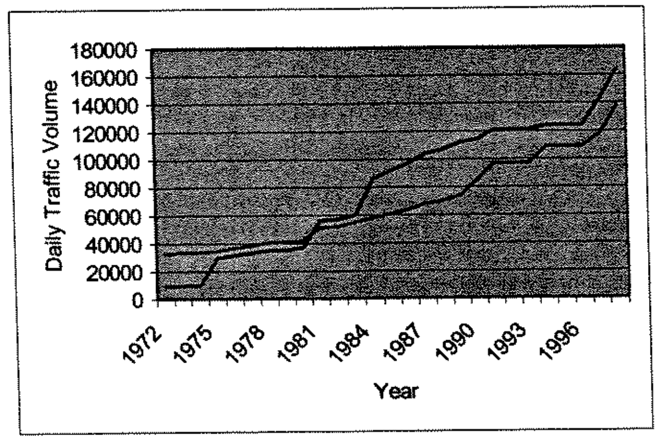
Stanley Boulevard extends from Pleasanton's First Street into downtown Livermore. There are no major intersections and only one driveway into the Shadow Cliffs Regional Recreation Area between Valley Avenue and Livermore's western city limits (Isabel Avenue). Railroad tracks exist along its northern side, on which the Altamont Commuter Express (ACE) trains travel. Stanley Boulevard has several signalized intersections within Livermore.

Dublin Boulevard is a major east-west arterial in the City of Dublin. Starting with the city limit at its western end, it traverses the city, paralleling I-580, to Tassajara Road at its eastern terminus. As eastern Dublin develops in the future, Dublin Boulevard will be connected to North Canyons Parkway in Livermore to provide a reliever route paralleling I-580. It also serves as an access route to the Dublin/Pleasanton BART station. During Friday afternoons when I-580 congestion is most severe, and also during incidents at other times on I-580, Dublin Boulevard is subjected to significant diverted freeway traffic avoiding the almost-stopped traffic on I-580.

TRAFFIC VOLUMES

This section describes traffic volumes on I-680 and the other study area freeways, including historical trends, current segment/interchange volumes, cordon/screenline volume aggregation, and peak spreading.

Historical Volume Trends



The graph to the right summarizes growth trends on I-680 from 1972 through 2002. The average annual growth rate on this freeway is about 5%. From 1997 through 2000 the volumes increased at an accelerated rate. Subsequent to 2000 a subjective judgement is that volumes in this corridor have decreased due to the changes in the economy, similar to the flat lines between 1990 and 1996. Overall, however, the average growth in the corridor over nearly three decades has been relatively constant, with higher growth spurts as the economy improves, and flatter growth in times of recession. In comparing 1997 to 2000 volumes on I-680, we find that overall, average daily traffic volumes on both the mainline and the ramps have increased in accordance with the long term growth rates (see below).

Similar growth rates have occurred on I-580 over the same period as with I-880, SR 84 and SR 262, because all are a part of the same system, and growth on I-680 is also expressed consistently on each of the routes serving the I-680 Corridor south of I-580.

Current Volumes

Daily traffic volumes are shown in the I-680 Corridor (Figure 3) and on I-680 including on and off ramps (Figure 4). The volumes in Figure 3 (excepting I-680) are 1997 volumes factored by a 20% assumed growth to 2000 for I-580, I-880, SR 237 and SR 262. Truck volume percentages range between 4% and 9% daily on I-680 between I-580 and the Montague Expressway, while I-580 truck volumes represent 10% to 12% of total daily volumes on I-580 between I-680 and Vasco Road. Surprisingly, I-880 truck volumes in the study area are only 5% from Auto Mall to Montague. SR 84 and SR 237 have truck volumes of 2 to 3% in the study area, while SR 262 trucks are about 6% of the total volumes.

Peak Hour Directional Distribution

Caltrans collected volumes in late 1999 and early 2000 along the I-680 mainline, and on and off ramps, including peak hour flows by hour by direction. Such information has not been collected systematically over a long period, so we cannot provide trend information for these characteristics. Peak hour, peak directional volumes cannot increase because the freeway is queued during more than four hours in both the a.m. and p.m. peak periods. An estimate of the true peak hour directional distribution has not been made in this task. The true directional distribution is a function of both a correction for queuing as well as a correction

FIGURE 3: 2000 VOLUMES

FIGURE 4: I-680 DAILY VOLUMES IN 2000

for peak hour spreading (e.g., the shift of peak hour traffic to other hours due to capacity limitations). Modeling in the earlier *I-680 Major Investment Study, Phase 2* estimated that the 1998 peak hour directional split in the I-680 Corridor was approximately 66% southbound and 34% northbound in the a.m. peak hour (total demand = 9,300), and 62% northbound and 38% southbound in the p.m. peak hour (total demand = 9,600).

Peak period, peak-direction flows on I-680 (and also I-580 and I-880) are typically less than capacity because the traffic is queued. At times along I-680, per-lane hourly flows drop to 1,400 or even less, even though counts show that the per-lane capacity of I-680 is close to the theoretical maximum of 2,200 cars per lane per hour (I-680 north of the Washington Boulevard interchange). This is consistent with the capacity manual speed/volume curves that show flows of 1,400 cars per lane per hour occurring both at near the free flow speed for the freeway as well as approximately 20 mph under congested, queued conditions.

Trucks

As explained above I-580 carries the highest truck volumes of all the study area freeways. As the major east-west connection between the Central Valley and the Bay Area, I-580 is a vital trucking route. Table 1 further illustrates this fact (based on 1998 volumes) by indicating the proportion of trucks that are heavy (five or more axles) on each of the study area freeways. Not only does I-580 carry by far the highest truck volumes of all the studied freeways, it also carries by far the highest proportion of heavy trucks (76 to 80 percent). I-680, SR 262 and SR 84 (west of I-680) form a second tier with 45 t 65 percent heavy trucks. I-880 and SR 237 form a third tier, with 25 to 45 percent heavy trucks. In should be noted that on I-880, although truck volumes are lower than on I-680 and I-580, heavy industrial land uses in the study area contribute to a high proportion of truck traffic entering and exiting the freeway.

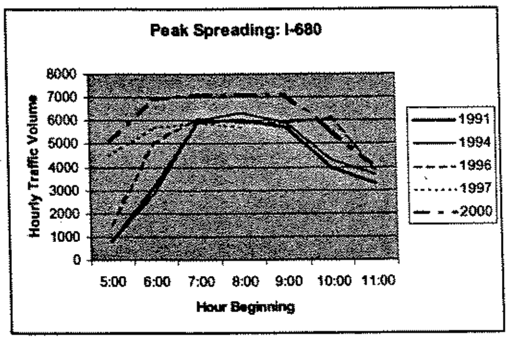
An earlier analysis by TJKM indicated that the 1997 volume of southbound heavy trucks, expressed as a percentage of the total southbound traffic volume, tends to increase throughout the a.m. peak period (even though it decreases slightly as a percentage of the total southbound truck volume). As the *Highway Capacity Manual* indicates, trucks use more freeway capacity than do standard passenger vehicles. The manual includes passenger car equivalents (PCE's) for trucks: one truck equals 3.0 passenger vehicles over rolling terrain (such as the Sunol Grade), and 1.5 over level terrain. Using these factors increases the effective vehicular volume on I-680 by two to four percent in the more level areas, and by sixteen percent over the Sunol Grade. Similarly, increases of five to six percent are calculated for I-580 (generally flat terrain) in the study area.

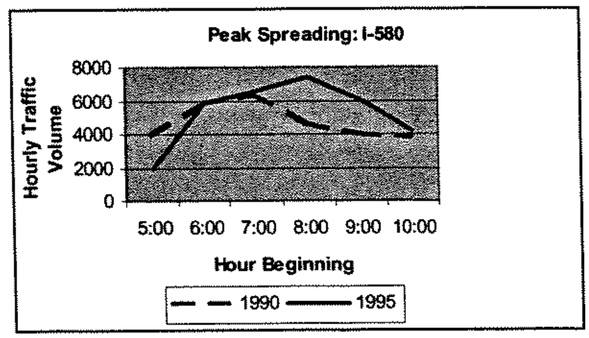
TABLE 1: EXISTING TRUCK CLASSIFICATION

		Existing	% Truck ADT by Axle				Computed Truck Volume by Axle			
		Truck ADT	2	3	4	5+	2	3	4	5+
I-580	Vasco Road	14,204	15.8	24.0	1.7	80.2	2,244	3,409	241	11,392
	SR 84	14,859	18.1	3.2	2.1	76.6	3,689	475	312	11,382
	I-680	16,732	19.1	2.8	2.1	76	3,196	468	351	12,716
I-680	Montague Expwy.	8,100	32.5	11.9	6.2	49.4	2,633	964	502	4,001
	SR 237	6,248	33.5	6.6	4.1	55.8	2,093	412	256	3,486
	SR 238 North	8,850	27.6	6.1	2.6	63.7	2,443	540	230	5,637
	SR 84 West	9,204	28.9	9.1	6.7	55.3	2,660	838	617	5,090
	SR 84 East	9,108	28.8	9.7	8.5	53	2,623	883	774	4,827
	I-580	9,656	32.4	4.7	3	59.9	3,129	454	290	5,784
I-880	Montague Expwy.	6,450	45.1	18.3	3.9	32.7	2,909	1,180	252	2,109
	SR 237	9,747	44.1	18.5	4.5	32.9	4,298	1,803	439	3,207
	SR 262	6,256	46	10.4	5	38.6	2,878	651	313	2,415
	Automall Pkwy.	7,830	45.6	10.7	7.1	36.6	3,570	838	556	2,866
SR 84	SR 238	499	48.2	6	0.5	45.3	241	30	2	226
	I680	387	87.4	8.2	3.8	0.6	338	32	15	2
	Stanley Blvd.	812	60.1	21.9	5.6	12.4	488	178	45	101
	I-580	1,190	64.7	18	2.1	15.2	770	214	25	181
SR 262	Mohave Dr.	3,472	29.6	5.3	3	62.1	1,028	184	104	2,156
(Mission)	Warm Srpings Blvd.	3,960	39.9	9.1	5.6	45.4	1,580	360	222	1,798
SR 237	Hillview Dr.	1,412	40.2	10.4	5.7	43.7	568	147	80	617
(Calaveras)	Abel St.	1,849	50.5	14.9	6.4	28.2	934	275	118	521
	I-880	3,034	56.6	13.8	4.3	25.3	1,717	419	130	768

Peak Spreading

As commute traffic on highway facilities reaches congested levels, commuters begin to change their travel patterns by either finding less-congested routes or commuting during off-peak hours. This second phenomenon, known as peak spreading, has begun to occur on study area freeways. It is becoming especially pronounced on I-680 and I-580 for which no uncongested, reasonable alternate routes exist in the study area. The volume source for these graphs are the Caltrans 2000 volume counts for I-680, and the 1998 volume counts by Caltrans for I-580. The I-680 counts are for I-680 north of Mission Boulevard, and the I-580 counts are for westbound west of Portola Avenue. The graphs below illustrate peak spreading.





On I-680 the southbound a.m. peak period essentially lasted from 7 a.m. to a little after 9 a.m. in 1991 and 1994. The 1996 data indicate the peak had extended well past 10 a.m., with traffic volumes also growing during the hour before 7 a.m. By 1997 the start of the a.m. peak was close to 5 a.m. Between 1994 and 1997 the I-680 southbound volume between 5 a.m. and 9 a.m. increased from 15,854 to 21,698, a 37 percent increase. Essentially all of this traffic growth occurred between 5 a.m. and 7 a.m. Note that in 1996 and 1997 the peak hour volumes *decreased* even while the total peak period volumes increased (this is due to increased queuing and congestion in the peak hours with lower corresponding flow rates). Note also that I-680 was widened from four to six lanes between 1991 and 1994. In 2000, however, the peak period starts before 6 a.m. and lasts until 10 a.m. It is unlikely that the peak will spread much before or after these times, because even commuters with flexible schedules eventually need to get to work before noon, and not much before 6 a.m. Note that in the 2000 counts the per-lane flows are exceeding 2350 cars per lane per hour in this three-lane section.

On I-580 only two data points area available for westbound a.m. traffic: 1990 and 1995. During this span of time the peak period spread to the later hours of the morning. In 1990 the a.m. peak period began around 6 a.m. and tapered off quickly after 8 a.m. By 1995 the peak period did not begin to taper off until after 9 a.m.

Peak spreading can result in deceptive effects on traffic volumes. Queuing and congestion can result in reduced mainline volumes during the peak hour, which can lead to the conclusion that capacity is available where it is not. An important further indicator of existing conditions is segment speed, which is discussed in the next section.

Average Vehicle Occupancy

Caltrans has counted vehicle occupancy on I-680 from 1998, and the values have not changed noticeably excepting p.m. peak occupancy between 2000 and 2001 in the northbound direction. Vehicle occupancy has been counted on the Sunol Grade in both directions (at the truck weight station). The March 2000 occupancy northbound in the p.m. peak was 1.36 from 3 to 4 p.m., dropping to 1.33 between 4 and 5 p.m., and to 1.25 after 5 p.m. High occupancy vehicles accounted for 18% of all vehicles. About 40% of all person trips were carried in high occupancy vehicles (includes bus and vanpools). Trucks and motorcycles are excluded from all totals. In March 2001 these values had dropped to 15% high occupancy vehicles carrying 27% of all person trips. Average vehicle occupancy is 1.25 from 3 to 4 p.m., 1.27 from 4 to 5 p.m., and 1.22 after 5 p.m.

In the southbound a.m. peak period, vehicle occupancy is quite low in comparison. Vehicle occupancy in March 2001 was 1.12 from 6 to 7 a.m., and 1.09 after 7 a.m. About 19% of all person trips are carried in the 8% high occupancy vehicles before 7 a.m., dropping to 15% after 7 a.m.

In 1997 average vehicle occupancy rates were surveyed and found to be higher than current levels with the a.m. peak occupancy north of SR 84 approximately 1.25 before 8 a.m., and dropping to 1.14 after 8 a.m. The occupancy of I-680 northbound; at Automall Parkway in March 1997 was found to be 1.35 in the p.m. peak, similar to later Caltrans surveys.

Video surveys were made of commute traffic on both I-680 and I-880 in the a.m. peak periods in 1998 and 2001. Vehicle occupancy rates on I-680 southbound from the video survey on the Sunol Grade were 1.17 in 1998 with 26% of all person trips in high occupancy vehicles (14% of vehicle traffic). On northbound I-680 in the a.m. peak period in November 2001, average vehicle occupancy was 1.17 as well. On I-880 southbound in the a.m. peak period in November 2001, vehicle occupancy was significantly higher at 1.25, most likely because of the HOV lanes.

This section describes the existing conditions that are most relevant to the users of the freeway facilities: peak period travel speeds and resulting travel times, which are the most understandable measures of congestion.

I-680

Floating car studies have been performed on southbound I-680 in 1997, 1998 and 2001 during the a.m. peak period by Caltrans. The graph below shows travel times between Stoneridge Way in Pleasanton and Calaveras Boulevard in Milpitas for 1997 and 2001. The distance is 20.7 miles, so at 65 mph, the travel time between these two points would be 19 minutes.

The southbound a.m. congestion is fairly apparent from this graph of the results of 14 runs in 1997 and 22 runs in 2001 between 5 a.m. and 11 a.m. The maximum time in 1997 was 70 minutes when the survey vehicle started south at 7 a.m. and 7:15 a.m. Maximum travel times in 2001 were only 56 minutes for runs starting at 8 a.m. and 8:30 a.m. Note there is little apparent congestion much before 7:30 a.m. in 2001 versus 5:45 a.m. in 1997. The reason is simple. In 1997 commuters starting their shift at 6 a.m. travelling to the NUMMI plant in Fremont backed up on Mission Boulevard onto the right-most I-680 southbound mainline lane, thereby reducing the mainline to only two effective lanes for all southbound traffic. Once this queue was started it was maintained through 9:30 a.m. because as southbound Mission off ramp volumes fell, Mission southbound on ramp volumes climbed which effectively maintained this location as the master bottleneck in the system.

The first phase of I-680 improvements is the southbound auxiliary lane between Automall Parkway and Mission Boulevard, and now queued traffic headed to NUMMI does not affect the three southbound lanes on the mainline, so traffic continues to flow freely until almost 7 a.m. Note that the congested speeds last from 6:00 a.m. through 10:30 a.m., or four and one-half hours. Congested speeds are essentially travel times of 25 minutes or more (average speeds less than 50 mph, or LOS F).

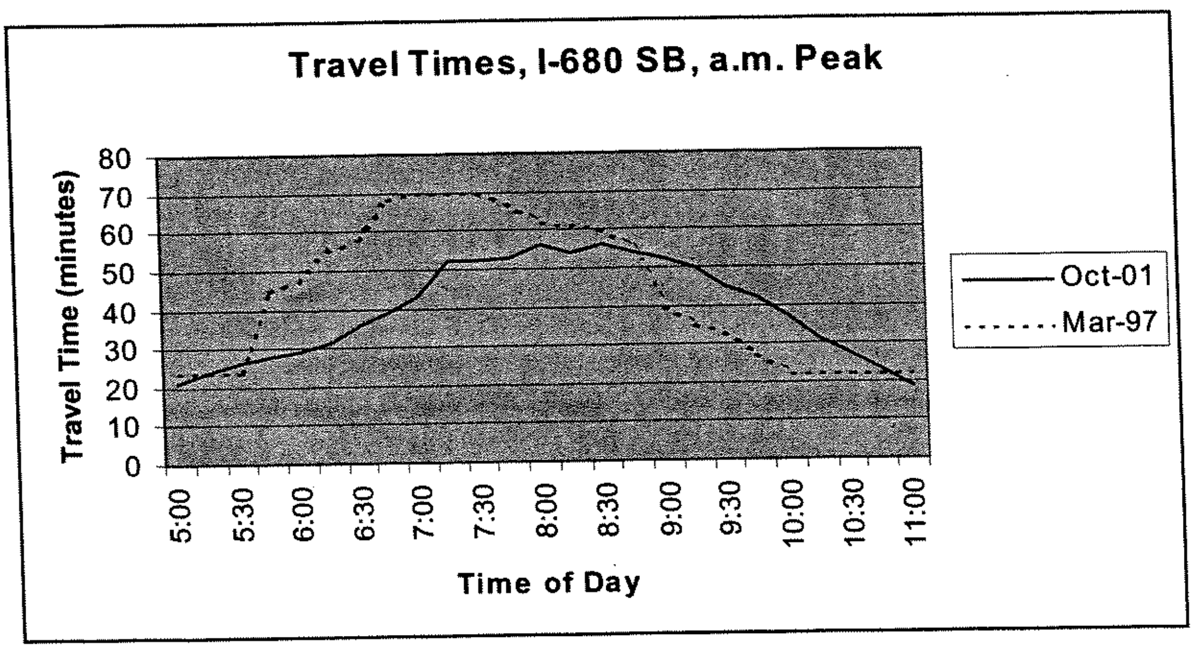
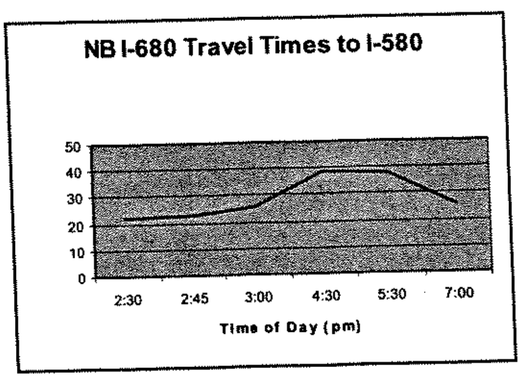
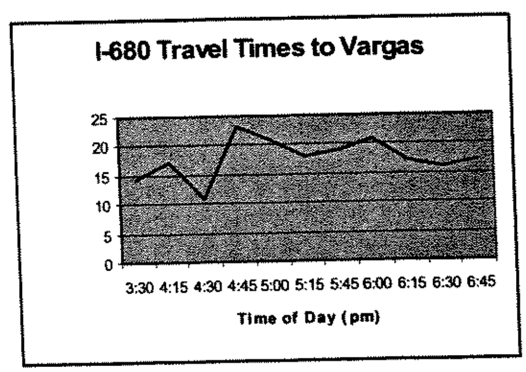


Figure 5A following this page shows I-680 southbound a.m. peak period segment speeds from Stoneridge to Calaveras for the floating car surveys taken in October 2001. It should be noted that peak period traffic volumes have probably dropped from levels recorded in early 2000 when there was full employment in Silicon Valley. In 2000 it is our subjective impression that traffic conditions were much worse for a far longer period than in 1997. In early 2000 the auxiliary lane had yet to be constructed, and traffic levels were 25% to 35% higher than in 1997. Today traffic levels are still probably higher than 1997. In the absence of data it is not possible to separate out the influence of the auxiliary lane and the apparent drop in peak period traffic volumes from early 2000. The average a.m. *peak hour* speed from I-580 to Calaveras is 18 mph.

Floating car surveys of p.m. peak period congestion are less complete. Surveys for northbound p.m. peak travel times were taken at various times between October 2000 and November 2001. Not all northbound runs were taken for the full length of the route from Calaveras to I-580; most were taken just from Calaveras to Vargas Road at the top of the Sunol Grade, a distance just over 9 miles. Figure 5B shows northbound segment speeds in the p.m. peak period. Congestion for the entire route is signified by travel times in excess of 25 minutes as with a.m. conditions, while congestion for travel times between Calaveras and Vargas are travel times in excess of 11 minutes (speeds less than 50 mph). In an earlier report, *I-680 Major Investment Study, Phase 2* conducted by the Metropolitan Transportation Commission between 1999 and 2001, a calibrated CORSIM model indicated a northbound p.m. peak hour travel time from Calaveras to I-580 as 44 minutes, or an average speed of 28 mph for the year 2000. Floating car studies for this same route in 2001 indicate a peak hour travel time of 39 minutes. The graphs below show surveys for the entire route as well as for the 9 mile section from Calaveras to Vargas in 2001. The model output was for the peak hour speed, not the peak period speed. The p.m. peak traffic congestion is probably not as bad for several reasons:

- the queuing back onto I-680 does not occur from the crossing arterial routes,
- north of the SR 238 interchange, more traffic generally leaves I-680 than gets on, so speeds are relatively high north of the Sunol Grade, and
- peaking is less abrupt, and the peak spreading in the p.m. peak lasts longer than in the a.m.





Northbound congestion lasts from 3 p.m. through 7 p.m. with travel times greater than 25 minutes. Similar results apply for floating car surveys from Calaveras to Vargas as well. Average *peak hour* speeds for northbound I-680 are 32 mph from Calaveras to I-580, and 27 mph from Calaveras to Vargas Road. The average *peak hour* speed in the CORSIM model is slower at 28 mph. The p.m. *peak hour* average speeds are almost 80% higher than the a.m. peak hour speeds.

FIGURE 5 A: PEAK PERIOD SEGMENT SPEEDS ON SB I-680 AM PEAK

FIGURE 5 B: PM PEAK SEGMENT SPEEDS ON NORTHBOUND I-680

In addition to the data on volumes and speeds, users were surveyed during the a.m. peak periods in 1998 and 2001 for various portions of the corridor. These surveys were taken using video cameras recording license plate numbers of all cars travelling on I-680 and I-880 at selected points. Surveys were taken in 1998 on the Sunol Grade for a.m. traffic on I-680, and in 2001 for southbound I-880 north of Automall Parkway and for northbound I-680 south of Montague Expressway. The registered owners of the surveyed vehicles were contacted and asked to return a questionnaire regarding their trip origins and destinations, trip purpose, and other trip characteristics. Figures 6a through 6c graphically summarize the origins and destinations of those surveyed in the corridor. Of the three locations, note that the longest commute distances are clearly on southbound I-680 over the Sunol Grade. An estimate of the average trip lengths for these users is approximately 34 miles, while average trip lengths for northbound I-680 and for southbound I-880 are closer to 15 miles to 20 miles.

On southbound I-680 94% of all a.m. peak period trips are home to work related with another 3% of the trips travelling from work to work (most likely truck responses).

For I-880 southbound, 90% of all trips were home to work, with 5% for home-based other purpose. The remainder were non-home-based trips to work (3%) and the remaining 2% are other to other. For I-680 northbound 86% of the trips are home-based work related, with an additional 7% home-based other. Another 4% are other-based work related, with the remainder (3%) as other to other. For all locations, the work-related commute trips are almost the only trip purposes represented.

FIGURE 6 A: SOUTHBOUND I-680 ORIGINS AND DESTINATIONS

FIGURE 6 B: NORTHBOUND I-680 ORIGINS AND DESTINATIONS

FIGURE 6 C: SOUTHBOUND I-880 ORIGINS AND DESTINATIONS

Appendix A – Interchange Geometry

FIGURE A 1: I-680 INTERCHANGE CONFIGURATIONS

FIGURE A 2: I-580 INTERCHANGE CONFIGURATIONS

Appendix B

Memorandum on Travel Demand Modeling Program and Mode Choice Specifications

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Memorandum

To: Emily Landin-Lowe, California Department of Transportation

Jean Hart, Alameda County Congestion Management Agency

From: David Ory

Date: April 2, 2002

Subject: I-680 Value Pricing Study: Travel Demand Modeling Program and Mode Choice Model Specifications

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A key aspect of the I-680 Value Pricing Study is the adjustment of the Metropolitan Transportation Commission's (MTC) Mode Choice Model to implement lower level Toll/No Toll sub-nests. The MTC Model currently has separate mode choice models for each of the following trip purposes:

- Home-Based Work
- Home-Based Shop
- Home-Based Social/Recreation
- Home-Based School
  - Grade School
  - High School
  - College
- Non-Home-Based

Each of the mode choice models are applied using MTC's LAYCAST software, developed in the FORTRAN programming language with each mode choice model applied using a separate sub-routine. Each of these sub-routines will be modified as part of the I-680 Value Pricing Study.

Modifying the sub-routines to accommodate the changes to the mode choice model structures involves the following steps:

- Compile the existing sub-routine using Microsoft Powerstation FORTRAN 4.0
- Modify the Organization of the Input and Output Matrices (see Appendix A)
  - Each sub-routine reads in and writes out a variety of MINTUP matrices. New input level-of-service and output trip table matrices will be read in and written out by the software. As a result, the organization (how the matrices are stored internally by the sub-routine) of the matrices needs to be adjusted.
- Modify Existing Arrays

    - Various arrays are used to store model coefficients, output trips, calibration adjustment factors, and probabilities. These arrays need to be adjusted to accommodate the new modes.
- Adjust Input Files to Accommodate New Modes
    - The models are calibrated using district-to-district or zone-to-zone "Delta" values, which are added to each modes alternative-specific constant. New Delta values are needed for the new modes.
- Modify Utility Equations and Computational Logic

Appendix A: Modified Code Array Structures, outlines the organization of various arrays for each of the sub-routines.

The final bullet point above, Modify Utility Equations and Computational Logic, is the focus of this document. Each of the trip purposes is discussed in more detail in the following pages. The existing model structure and utility equations as well as the proposed changes for each of the models is discussed for each trip purpose individually.

In addition to the resident travel models, the Internal/External Trip and Truck Trip models are enhanced with logit mode split models to produce Toll and No Toll trips. Separate sections outline these procedures.

HOME-BASED WORK

The Home-Based Work section contains general comments regarding computational methods and input files, which are valid for all the trip purposes.

Home-Based Work Peak Period

The structure of the existing Home-Based Work Mode Choice Model, as recently modified by the Santa Clara County Valley Transportation Authority (SCVTA), is shown in Figure 1.

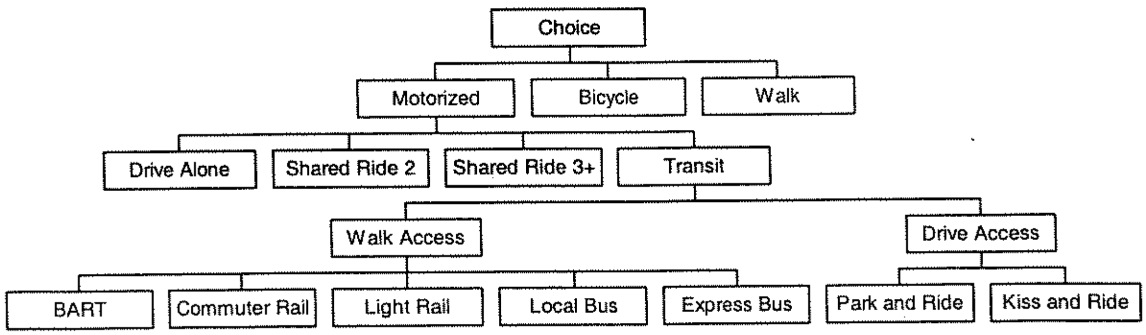

Figure 1: Existing Home-Based Work Mode Choice Model Structure

The nesting coefficients are as follows:

- Motorized Nest Theta = 0.9208
- Transit Nest Theta = 0.7194
- Walk Access Transit Nest Theta = 0.6835
- Drive Access Transit Nest Theta = 0.6835

For the I-680 Value Pricing Study, the utility equations for the Drive Alone, Shared Ride 2, and Shared Ride 3+ will be modified to include Toll and No Toll nests. To provide a basis for comparison, the existing utility equations for the auto modes are shown below in Equations 1, 2, and 3. Please refer to MTC documentation[1] for an explanation of variable names.

While the Home-Based Work model segments trips by income quartiles and auto ownership, the Drive Alone and Shared Ride 2 and 3+ utility equations are constant across these wealth categories.

Please Note: In expressions throughout this document, model coefficients are denoted using β, with variable-specific subscripts.

$$U_{DA} = \beta_{DA} + \beta_{WHH} \cdot WHHG(Q) + \beta_{PHH} \cdot PHH + \beta_{INCL1DA} \cdot HHINCQ1 + \beta_{IVTT} \cdot IVTT$$
$$+ \beta_{WALK} \cdot OVT + \beta_{COST} \cdot COST + \beta_{COREJD} \cdot COREJ(J)$$

Equation 1: Existing Drive Alone Mode Utility Equation (All Auto Ownership Levels)

[1] Travel Demand Models for the San Francisco Bay Area (BAYCAST-90). Technical Summary. Metropolitan Transportation Commission, Oakland, California, June 1997.

$$U_{SR2} = \beta_{SR2} + \beta_{MWHH} \cdot MWHHG(Q) + \beta_{INCL1SR} \cdot HHINCQ1 + \beta_{IVTT} \cdot IVTT$$
$$+ \beta_{WALK} \cdot OVT + \beta_{COST} \cdot COST$$

Equation 2: Existing Shared Ride 2 Mode Utility Equation (All Auto Ownership Levels)

$$U_{SR3} = \beta_{SR3} + \beta_{INCL1SR} \cdot HHINCQ1 + \beta_{IVTT} \cdot IVTT$$
$$+ \beta_{WALK} \cdot OVT + \beta_{COST} \cdot COST$$

Equation 3: Existing Shared Ride 3+ Mode Utility Equation (All Auto Ownership Levels)

The strategy behind the modeling component of the I-680 Value Pricing Study is to consider the decision of using a Toll facility as a mode choice. As such, each of the auto modes needs to possess a Toll/No Toll nesting structure. Such a structure is proposed for the Home-Based Work model and is shown in Figure 2.

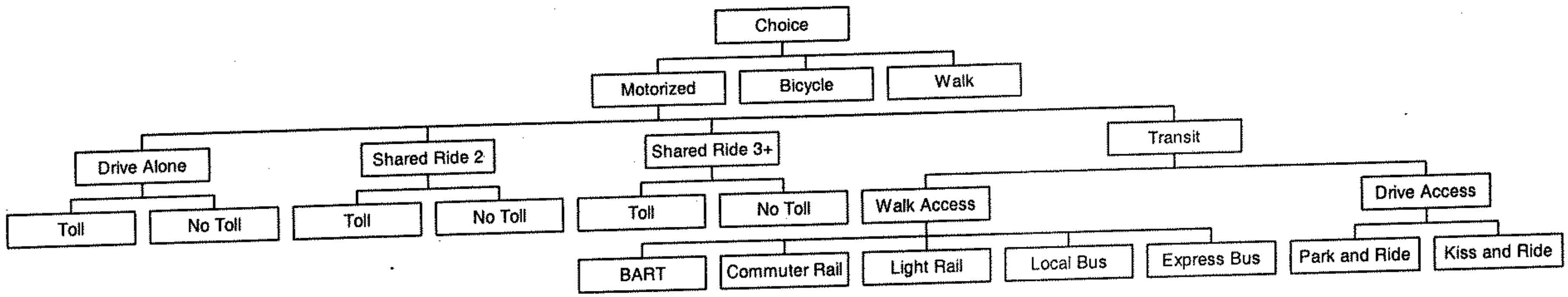

Figure 2: Proposed Home-Based Work Mode Choice Model Structure

The following nesting coefficients would be used in the model structure:

- Motorized Nest Theta = 0.9208
- Transit Nest Theta = 0.7194
- Walk Access Transit Nest Theta = 0.6835
- Drive Access Transit Nest Theta = 0.6835
- Drive Alone Toll/No Toll Nest Theta (θ_{DA}) = 1.000
- Shared Ride 2 Toll/No Toll Nest Theta (θ_{S2}) = 0.823
- Shared Ride 3+ Toll/No Toll Nest Theta (θ_{S3}) = 0.783

The Toll/No Toll nesting coefficients were transferred from Home-based Work models recently estimated for the Houston-Galveston Region[1]. The Houston-Galveston Region is unique in its combination of an extensive Toll road network and special surveys, which capture the behavior of the Toll facility users. The data recently collected and analyzed in Houston provides a comprehensive representation of Toll user's behavior.

Implementing the lower level Toll/No Toll nesting structure will require the application program to read in an additional level-of-service matrix. This matrix will contain the following tables:

- Drive Alone Toll in-vehicle travel time
- Drive Alone Toll cost (Toll cost)
- Drive Alone Toll operating cost
- Drive Alone No Toll in-vehicle travel time
- Drive Alone No Toll cost
- Shared Ride 2 Toll in-vehicle travel time
- Shared Ride 2 Toll cost (Toll cost)
- Shared Ride 2 operating cost
- Shared Ride 2 No Toll in-vehicle travel time
- Shared Ride 2 No Toll cost
- Shared Ride 3+ Toll in-vehicle travel time
- Shared Ride 3+ Toll cost (Toll cost)
- Shared Ride 3+ Toll operating cost
- Shared Ride 3+ No Toll in-vehicle travel time
- Shared Ride 3+ No Toll cost

The application software will then output six additional trip tables as well as the fourteen it currently outputs. The following trip tables will be output by the application program:

- Drive Alone Total

[1] *DRAFT – Home-based Work Mode Choice Model Estimation,* Houston-Galveston Area Council (H-GAC), PB Consult, March 2002.

- Shared Ride 2 Total
- Shared Ride 3+ Total
- Transit Walk Access Total
- Transit Auto Access Total
- Bicycle
- Walk Only
- BART Walk Access
- Commuter Rail Walk Access
- Light Rail Walk Access
- Express Bus Walk Access
- Local Bus Walk Access
- Park and Ride
- Kiss and Ride
- Drive Alone Toll (new)
- Drive Alone No Toll (new)
- Shared Ride 2 Toll (new)
- Shared Ride 2 No Toll (new)
- Shared Ride 3+ Toll (new)
- Shared Ride 3+ No Toll (new)

The proposed utility equations for the Drive Alone Toll and No Toll modes are shown in Equations 4 and 5. The No Toll equation is identical to the existing Drive Alone equation (Equation 2). The Toll equation includes the Toll cost, and the travel time is based on the Toll path. For all the "Proposed" equations described in this document, the following naming conventions are used:

- $IVTT_{NT}$ – Refers to the in-vehicle travel time for the No Toll path (specific to each mode, i.e. Drive Alone IVTT is not equal to Shared Ride IVTT)
- $IVTT_{T}$ – In-vehicle travel time for the Toll path (specific to each mode)
- $COST_{NT}$ – Operating cost of the No Toll path (specific to each mode)
- $COST_{T}$ – Operating cost of the Toll path (specific to each mode)
- TOLL – The Toll cost of using the Toll path

During application, the Toll mode is considered available only if it provides a travel time savings ($IVTT_{NT}$ - $IVTT_{T}$). For the I-680 Value Pricing Study, any time savings, regardless of size, allows the Toll Mode to be available (see Table 1). This assumption may change as testing of the approach progresses.

Introducing sub-modes in a Drive Alone nest increases the utility of the Drive Alone mode when both sub-modes are available. For this reason, the Drive Alone No Toll and Drive Alone Toll modes need to be adjusted when both are available. In another words, if a Toll lane is introduced into the network with a zero Toll, it should have the same impact as adding another main flow lane.

The adjustment needed was calibrated by insuring a sample of district-to-district pairs (those in the proposed Toll corridor) produce the same results when the Toll is introduced. A coefficient, β_B, is added to the No Toll Utility equation only when the Toll Mode is available (see Table 1). This coefficient reduces the overall attractiveness of the Drive Alone Mode.

$$U_{DANT} = \beta_{DANT} + \beta_{WHH} \cdot WHHG(Q) + \beta_{PHH} \cdot PHH + \beta_{INCL1DA} \cdot HHINCQ1 + \beta_{IVTT} \cdot IVTT_{NT} \\ + \beta_{WALK} \cdot OVT + \beta_{COST} \cdot COST_{NT} + \beta_{COREJD} \cdot COREJ(J) + (\beta_B)$$

Equation 4: Proposed Drive Alone No Toll Mode Utility Equation (Auto Own. 1 and 2)

$$U_{DAT} = \beta_{DAT} + \beta_{WHH} \cdot WHHG(Q) + \beta_{PHH} \cdot PHH + \beta_{INCL1DA} \cdot HHINCQ1 + \beta_{IVTT} \cdot IVTT_T \\ + \beta_{WALK} \cdot OVT + \beta_{COST} \cdot (COST_T + TOLL) + \beta_{COREJD} \cdot COREJ(J) + \beta_B$$

Equation 5: Proposed Drive Alone Toll Mode Utility Equation (Auto Own. 1 and 2)

The Drive Alone utility can then be calculated from the Toll and No Toll utility equations. First, the LogSum of the Drive Alone mode is calculated as shown in Equation 6. Next, the composite Drive Alone utility is calculated as shown in Equation 7. A separate Drive Alone utility is developed for each auto ownership category. However, Equations 6 and 7 simply show a generic calculation. The same method will be used for all composite utility calculations developed for the I-680 study.

$$LogSum_{DA} = \ln(e^{U_{DAT}/\theta_{DA}} + e^{U_{DANT}/\theta_{DA}})$$

Equation 6: Proposed Drive Alone Mode LogSum (Generic Auto Ownership Level)

$$U_{DA} = \theta_{DA} \cdot LogSum_{DA}$$

Equation 7: Proposed Drive Alone Mode Utility Equation (Generic Auto Ownership Level)

The application software now uses the Drive Alone utility exactly as it was without the Toll/No Toll nesting structure. And, if no "value" Tolls are present in the network, the model will produce identical results as without the Toll/No Toll nesting structure.

The MTC mode choice models are calibrated using a separate file, which reads in alternative-specific constants (referred to as "Deltas") and adds them to the hard-coded alternative-specific constants. Each of the new Toll/No Toll sub-modes contains a new Delta value, which is set to zero for the I-680 study but can be used to calibrate future models. The existing Drive Alone Delta is added to the composite Drive Alone utility equation. This method of adding new Deltas for the new modes and leaving the existing Deltas at the composite utility level is used for each of the proposed utility equations across all trip purposes.

Table 1: Proposed Drive Alone Toll Model Coefficients

Coefficient	Auto Ownership Level	Income Quartile	Value
β_B	All	1	-0.2915
		2	-0.1399
		3	-0.1284
		4	-0.3066
Initial Minimum Time Savings (may change during testing)	All	All	0.10 minutes

The proposed utility equations for the Shared Ride 2 Toll/No Toll modes are shown in Equations 8 and 9. The No Toll equation is identical to Equation 3. The structure and application of the Shared Ride 2 equations are identical to the Drive Alone equations. Again, β_B is only included in the No Toll equation when the Toll Mode is available.

$$\begin{aligned} U_{SR2NT} = {} & \beta_{SR2NT} + \beta_{MWHH} \cdot MWHHG(Q) + \beta_{INCL1SR} \cdot HHINCQ1 + \beta_{IVTT} \cdot IVTT_{NT} \\ & + \beta_{WALK} \cdot OVT + \beta_{COST} \cdot COST_{NT} + (\beta_B) \end{aligned}$$

Equation 8: Proposed Shared Ride 2 No Toll Mode Utility Equation (All Auto Own. Levels)

$$\begin{aligned} U_{SR2T} = {} & \beta_{SR2T} + \beta_{MWHH} \cdot MWHHG(Q) + \beta_{INCL1SR} \cdot HHINCQ1 + \beta_{IVTT} \cdot IVTT_{T} \\ & + \beta_{WALK} \cdot OVT + \beta_{COST} \cdot (COST_T + TOLL) + \beta_B \end{aligned}$$

Equation 9: Proposed Shared Ride 2 Toll Mode Utility Equation (All Auto Own. Levels)

Table 2: Proposed Shared Ride 2 Toll Model Coefficients

Coefficient	Auto Ownership Level	Income Quartile	Value
β_B	All	1	-0.1828
		2	-0.0540
		3	-0.0645
		4	-0.1640
Initial Minimum Time Savings (may change during testing)	All	All	0.10 minutes

The proposed utility equations for the Shared Ride 3+ Toll/No Toll modes are shown in Equations 10 and 11. The proposed No Toll equation is identical to the existing Shared Ride 3+ equation (Equation 4). The parameters for the model are shown in Table 3.

$$\begin{aligned} U_{SR3NT} &= \beta_{SR3NT} + \beta_{INCL1SR} \cdot HHINCQ1 + \beta_{IVTT} \cdot IVTT_{NT} \\ &+ \beta_{WALK} \cdot OVT + \beta_{COST} \cdot COST_{NT} + (\beta_B) \end{aligned}$$

Equation 10: Proposed Shared Ride 3+ No Toll Mode Utility Equation (All Auto Own Levels)

$$\begin{aligned} U_{SR3T} &= \beta_{SR3T} + \beta_{INCL1SR} \cdot HHINCQ1 + \beta_{IVTT} \cdot IVTT_T \\ &+ \beta_{WALK} \cdot OVT + \beta_{COST} \cdot (COST_T + TOLL) + \beta_B \end{aligned}$$

Equation 11: Proposed Shared Ride 3+ Toll Mode Utility Equation (Auto Own. Level 0)

Table 3: Proposed Shared Ride 3+ Toll Model Coefficients

Coefficient	Auto Ownership Level	Income Quartile	Value
β_B	All	1	-0.0589
		2	-0.0409
		3	-0.0223
		4	-0.1749
Initial Minimum Time Savings (may change during testing)	All	All	0.10 minutes

Home-Based Work Off-Peak Period

The structure of the Off-Peak period Home-Based Work mode choice model is nearly identical to the Peak period model. The following differences are found in the Off-Peak models:

- Transit – Drive Access Modes are not considered (Park and Ride, Kiss and Ride)
- The Auto Cost is divided by Auto Occupancy (assumed 3.5 for Shared Ride 3+)

The same modifications were made to the Off-Peak models in an identical fashion as the Peak models and the same coefficients were used. Revised utility equations are not shown.

HOME-BASED SHOP

The modifications made to the Home-Based Shop mode choice model are nearly identical to those made to the Home-Based Work model.

Home-Based Shop Peak Period

The structure of the existing Home-Based Shop Mode Choice Model is shown in Figure 3.

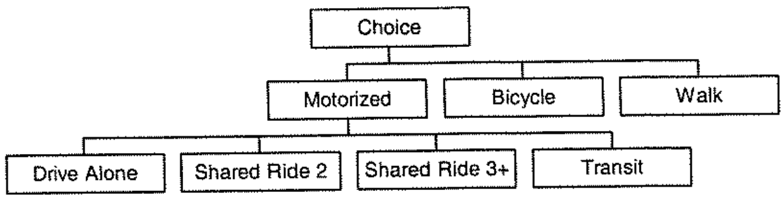

Figure 3: Existing Home-Based Shop Mode Choice Model Structure

The nesting coefficient is as follows:

- Motorized Nest Theta = 0.4847

The existing Drive Alone, Shared Ride 2, and Shared Ride 3+ utility equations are shown in Equations 12, 13, and 14.

$$U_{DA} = \beta_{DA} + \beta_{LNHHINCD} \cdot LNHHINC + \beta_{TIME} \cdot (IVTT + OVTT) + \beta_{LNCOST} \cdot \ln(COST) + \beta_{LNAREAD} \cdot LNARDI + \beta_{ZWHH} \cdot ZWKR$$

Equation 12: Existing Drive Alone Mode Utility Equation (All Auto Ownership Levels)

$$U_{SR2} = \beta_{SR2} + \beta_{LNPHH2} \cdot LNHHSIZE + \beta_{CLNHHINCS} \cdot LNHHINC + \beta_{TIME} \cdot (IVTT + OVTT) + \beta_{LNCOST} \cdot \ln(COST) + \beta_{LNAREAD} \cdot LNARDI$$

Equation 13: Existing Shared Ride 2 Mode Utility Equation (All Auto Ownership Levels)

$$U_{SR3} = \beta_{SR3} + \beta_{LNPHH3} \cdot LNHHSIZE + \beta_{TIME} \cdot (IVTT + OVTT) + \beta_{LNCOST} \cdot \ln(COST) + \beta_{LNAREAD} \cdot LNARDI$$

Equation 14: Existing Shared Ride 3+ Mode Utility Equation (All Auto Ownership Levels)

The proposed structure for the Home-Based Shop Model incorporates a lower-level Toll/No Toll nesting structures for each of the auto modes. The proposed model structure is shown in Figure 4.

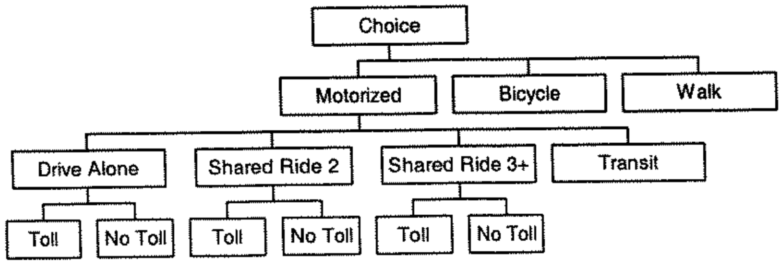

Figure 4: Proposed Home-Based Shop Mode Choice Model Structure

The following nesting coefficients would be used in the model structure:

- Motorized Nest Theta = 0.4847
- Drive Alone Toll/No Toll Nest Theta = 1.000
- Shared Ride 2 Toll/No Toll Nest Theta = 0.823
- Shared Ride 3+ Toll/No Toll Nest Theta = 0.783

The nesting coefficients for the Toll/No Toll nests are again taken from the Houston Home-based Work estimates. Unfortunately, estimates were not available for other trip purposes at the time of this work. Because the Motorized Nest Theta is quite low the influence of the Toll/No Toll nesting coefficients on the other modes is greatly diminished.

Identical to the Home-Based Work Model, the application software will be modified to read in an additional level-of-service matrix, which will contain the in-vehicle travel time and travel cost (operating and Toll cost) for the Drive Alone and Shared Ride modes, segmented by Toll and No Toll. Also, the application will output an additional six trip tables, containing the three auto modes, segmented by Toll and No Toll.

The proposed utility equations are developed in a manner similar to the Home-Based Work model. The Drive Alone Toll and No Toll utility expressions are shown in Equations 15 and 16. The No Toll expression is identical to the existing utility equation (Equation 12). The proposed model coefficients and minimum time savings are shown in Table 4. The composite Drive Alone Utility expression is calculated in an identical fashion as the Home-Based Work model (see Equations 7 and 8). Again, β_B is only added to the No Toll equation when the Toll Mode is available.

$$U_{DANT} = \beta_{DANT} + \beta_{LNHHINCD} \cdot LNHHINC + \beta_{TIME} \cdot (IVTT_{NT} + OVTT) + \beta_{LNCOST} \cdot \ln(COST_{NT}) + \beta_{LNAREAD} \cdot LNARDI + \beta_{ZWHH} \cdot ZWKR + (\beta_B)$$

Equation 15: Proposed Drive Alone No Toll Mode Utility Equation (Auto Own Level 1 and 2)

$$U_{DAT} = \beta_{DAT} + \beta_{LNHHINCD} \cdot LNHHINC + \beta_{TIME} \cdot (IVTT_T + OVTT) + \beta_{COST} \cdot \ln(COST_T + TOLL) + \beta_{LNAREAD} \cdot LNARDI + \beta_{ZWHH} \cdot ZWKR + \beta_B$$

Equation 16: Proposed Drive Alone Toll Mode Utility Equation (Auto Own Level 1 and 2)

Table 4: Proposed Drive Alone Toll Model Coefficients

Coefficient	Auto Ownership Level	Value
β_B	All	-0.2500
Initial Minimum Time Savings (may change during testing)	All	0.10 Minutes

The proposed utility equations for the Shared Ride 2 Toll/No Toll modes are shown in Equations 17 and 18. The proposed model coefficients are shown in Table 5.

$$U_{SR2NT} = \beta_{SR2NT} + \beta_{LNPHH2} \cdot LNHHSIZE + \beta_{LNHINCS} \cdot LNHHINC + \beta_{TIME} \cdot (IVTT_{NT} + OVTT) + \beta_{LNCOST} \cdot \ln(COST_{NT}) + \beta_{LNAREAD} \cdot LNARDI + (\beta_B)$$

Equation 17: Proposed Shared Ride 2 No Toll Mode Utility Equation (All Auto Own. Levels)

$$U_{SR2T} = \beta_{SR2T} + \beta_{LNPHH2} \cdot LNHHSIZE + \beta_{LNHINCS} \cdot LNHHINC + \beta_{TIME} \cdot (IVTT_T + OVTT) + \beta_{COST} \cdot \ln(COST_T + TOLL) + \beta_{LNAREAD} \cdot LNARDI + \beta_B$$

Equation 18: Proposed Shared Ride 2 Toll Mode Utility Equation (All Auto Own Levels)

Table 5: Proposed Shared Ride 2 Toll Model Coefficients

Coefficient	Auto Ownership Level	Value
β_B	All	-0.2000
Initial Minimum Time Savings (may change during testing)	All	0.10 Minutes

The proposed utility equations for the Shared Ride 3+ Toll/No Toll modes are shown in Equations 19 and 20. The proposed model coefficients are shown in Table 6.

$$U_{SR3NT} = \beta_{SR3NT} + \beta_{LNPHH3} \cdot LNHHSIZE + \beta_{TIME} \cdot (IVTT_{NT} + OVTT) + \beta_{LNCOST} \cdot \ln(COST_{NT}) + \beta_{LNAREAD} \cdot LNARDI + (\beta_B)$$

Equation 19: Proposed Shared Ride 3+ No Toll Mode Utility Equation (All Auto Own Levels)

$$U_{SR3T} = \beta_{SR3T} + \beta_{CLNPHH3} \cdot LNHHSIZE + \beta_{TIME} \cdot (IVTT_{TOLL} + OVTT)$$
$$+ \beta_{COST} \cdot \ln(COST_T + TOLL) + \beta_{LNAREAD} \cdot LNARDI + \beta_B$$

Equation 20: Proposed Shared Ride 3+ Toll Mode Utility Equation (All Auto Own Levels)

Table 6: Proposed Shared Ride 3+ Toll Model Coefficients

Coefficient	Auto Ownership Level	Value
β_B	All	-0.2485
Initial Minimum Time Savings (may change during testing)	All	0.10 Minutes

Home-Based Shop Off-Peak Period

The Home-Based Shop Off-Peak period model is only slightly different from the Peak period model. The following differences are present in the Off-Peak period model:

- The Auto Cost is divided by the Auto Occupancy (assumed 3.5 for Shared Ride 3+)
- A travel time penalty is assessed to the Shared Ride Modes
  - S2PEN = 5.0 minutes
  - S3PEN = 7.0 minutes

The same modifications were made to the Off-Peak models as were made to the Peak models; Toll and No Toll lower level nests were added to the auto utility equations with the same coefficients as used in the Peak period models.

HOME-BASED SOCIAL/RECREATION

The modifications made to the Home-Based Social/Recreation model are essentially the same as those made to the Home-Based Work and Home-Based Shop models.

Home-Based Social/Recreation Peak Period

The structure of the existing Home-Based Social/Recreation (Soc/Rec) Mode Choice model is shown in Figure 5. The structure differs from the Home-Based Work and Shop models in that the Shared Ride 2 and 3+ modes are in a "Group" nest with transit.

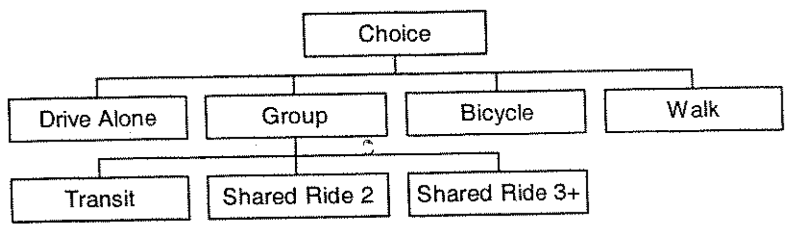

Figure 5: Existing Home-Based Soc/Rec Mode Choice Model Structure

The nesting coefficient for this structure is:

- Group Nest Theta = 0.6271

As with the previous models, the Drive Alone, Shared Ride 2, and Shared Ride 3+ modes will be expanded to include a Toll/No Toll nest. The existing utility equations for these three modes are shown in Equations 21, 22, and 23.

$$U_{DA} = \beta_{DA} + \beta_{IVTT} \cdot IVTT + \beta_{OVTT} \cdot OVTT + \beta_{LNCOST} \cdot \ln(COST)$$

Equation 21: Existing Drive Alone Mode Utility Equations (All Auto Own Levels)

$$U_{SR2} = \beta_{SR2} + \beta_{LNHHINC} \cdot LNHHINC + \beta_{IVTT} \cdot IVTT + \beta_{OVTT} \cdot OVTT + \beta_{LNCOST} \cdot \ln(COST)$$

Equation 22: Existing Shared Ride 2 Mode Utility Equation (All Auto Own Levels)

$$U_{SR3} = \beta_{SR3} + \beta_{LNPHH} \cdot LNHHSIZE + \beta_{IVTT} \cdot IVTT + \beta_{OVTT} \cdot OVTT + \beta_{LNCOST} \cdot \ln(COST)$$

Equation 23: Existing Shared Ride 3+ Mode Utility Equation (All Auto Own Levels)

The proposed structure for the Home-Based Soc/Rec model is shown in Figure 6.

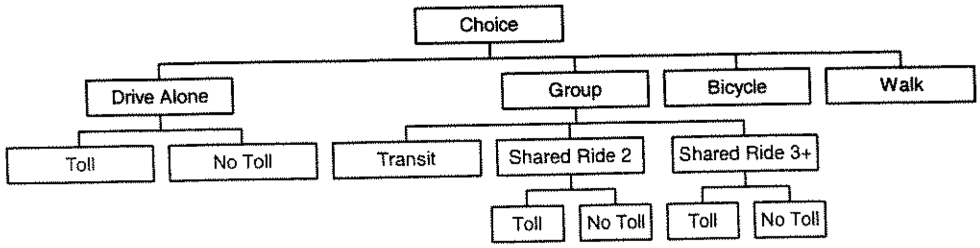

Figure 6: Proposed Home-Based Soc/Rec Mode Choice Model Structure

The following nesting coefficients would be used in the model structure:

- Group Nest Theta = 0.6271
- Drive Alone Toll/No Toll Nest Theta = 1.000
- Shared Ride 2 Toll/No Toll Nest Theta = 0.823
- Shared Ride 3+ Toll/No Toll Nest Theta = 0.783

In absence of any other quality data, the Houston Model estimates were again used for the nesting coefficient specifications.

Identical to the Home-Based Work and Shop models, the application software will be modified to read in an additional level-of-service matrix, which will contain the in-vehicle travel time and travel cost for the Drive Alone and Shared Ride modes, segmented by Toll and No Toll. Also, the application will output an additional six trip tables, containing the three auto modes, segmented by Toll and No Toll.

The proposed utility equations are developed in a manner similar to the Home-Based Work model. The Drive Alone Toll and No Toll utility expressions are shown in Equations 24 and 25. The No Toll expression is identical to the existing utility equation (Equation 21). The proposed model coefficients and minimum time savings value are shown in Table 7.

$$U_{DANT} = \beta_{DANT} + \beta_{IVTT} \cdot IVTT_{NT} + \beta_{OVTT} \cdot OVTT + \beta_{LNCOST} \cdot \ln(COST_{NT}) + (\beta_B)$$

Equation 24: Proposed Drive Alone No Toll Mode Utility Equation (All Auto Own Levels)

$$U_{DAT} = \beta_{DAT} + \beta_{IVTT} \cdot IVTT_T + \beta_{OVTT} \cdot OVTT + \beta_{COST} \cdot \ln(COST_T + TOLL) + \beta_B$$

Equation 25: Proposed Drive Alone Toll Mode Utility Equation (All Auto Own Levels)

Table 7: Proposed Drive Alone Toll Model Coefficients

Coefficient	Auto Ownership Level	Value
β_B	All	-0.1377
Initial Minimum Time Savings (may change during testing)	All	0.10 Minutes

The proposed utility equations for the Shared Ride 2 Toll/No Toll modes are shown in Equations 26 and 27. Again, the No Toll equation is identical to the existing Shared Ride 2 utility equation shown in Equation 24, and the model coefficients and parameters are shown in Table 8.

$$\begin{aligned} U_{SR2NT} = {} & \beta_{SR2NT} + \beta_{LNHHINC} \cdot LNHHINC + \beta_{IVTT} \cdot IVTT_{NT} + \beta_{OVTT} \cdot OVTT \\ & + \beta_{LNCOST} \cdot \ln(COST_{NT}) + (\beta_B) \end{aligned}$$

Equation 26: Proposed Shared Ride 2 No Toll Mode Utility Equation (All Auto Own Levels)

$$\begin{aligned} U_{SR2T} = {} & \beta_{SR2T} + \beta_{LNHHINC} \cdot LNHHINC + \beta_{IVTT} \cdot IVTT_{T} + \beta_{OVTT} \cdot OVTT \\ & + \beta_{LNCOST} \cdot \ln(COST_{T} + TOLL) + \beta_B \end{aligned}$$

Equation 27: Proposed Shared Ride 2 Toll Mode Utility Equation (All Own Levels)

Table 8: Proposed Shared Ride 2 Toll Model Coefficients

Coefficient	Auto Ownership Level	Value
β_B	All	-0.1332
Initial Minimum Time Savings (may change during testing)	All	0.10 Minutes

The proposed utility equations for the Shared Ride 3+ Toll/No Toll modes are shown in Equations 28 and 29; the new coefficient and parameter are shown in Table 9.

$$U_{SR3NT} = \beta_{SR3NT} + \beta_{LNPHH} \cdot LNHHSIZE + \beta_{IVTT} \cdot IVTT_{NT} + \beta_{OVTT} \cdot OVTT$$
$$+ \beta_{LNCOST} \cdot \ln(COST_{NT}) + (\beta_B)$$

Equation 28: Proposed Shared Ride 3+ Toll Mode Utility Equation (All Auto Own Levels)

$$U_{SR3T} = \beta_{SR3T} + \beta_{LNPHH} \cdot LNHHSIZE + \beta_{IVTT} \cdot IVTT_T + \beta_{OVTT} \cdot OVTT$$
$$+ \beta_{COST} \cdot \ln(COST_T + TOLL) + \beta_B$$

Equation 29: Proposed Shared Ride 3+ Toll Mode Utility Equation (All Auto Own Levels)

Table 9: Proposed Shared Ride 3+ Toll Model Coefficients

Coefficient	Auto Ownership Level	Value
β_B	All	-0.0000
Initial Minimum Time Savings (may change during testing)	All	0.10 Minutes

Home-Based Soc/Rec Off-Peak Period

The Off-Peak period models for the Home-Based Soc/Rec purpose differ from the Peak period models in a manner identical to how the Home-Based Shop Peak and Off-Peak models differ. The specific changes are as follows:

- The Auto Cost is divided by the Auto Occupancy (assumed 3.5 for Shared Ride 3+)
- A travel time penalty is assessed to the Shared Ride Modes
  - S2PEN = 5.0 minutes
  - S3PEN = 7.0 minutes

As in the other models, the same changes were made to the Off-Peak period models and the same coefficients were used in the Toll/No Toll lower-level nests.

HOME-BASED SCHOOL

The three Home-Based school trip purposes (Grade School, High School, and College) currently have a nesting structure that segments Vehicle Drivers from Vehicle Passengers. While such a formulation may capture the true behavior of a student's mode choice, it causes problems when performing trip assignment. The highway network segments links for use by all vehicles, vehicles with 2 or more persons, and vehicles with 3 or more persons. The Home-Based School model outputs only Vehicle Driver and Vehicle Passenger trips, providing no information on the occupancy of the vehicle.

The proposed mode choice model will not change the Grade School model. The Grade School model is applied only to the students making the trip to these schools. As no Grade School students can drive, they produce no auto trips.

The proposed mode choice model structures for the other Home-Based School trip purposes suggest replacing the Vehicle Driver and Vehicle Passenger modes with Drive Alone, Shared Ride 2, and Shared Ride 3+ modes. Such a strategy requires re-calibrating the model to observed data. The re-calibration of the mode choice models is discussed in *I-680 Value Pricing Study: Travel Demand Modeling Validation*[2].

HOME-BASED SCHOOL – HIGH SCHOOL

The Home-Based School – High School model segments vehicle drivers from vehicle passengers and contains a "group" nesting structure. The existing model structure is shown in Figure 7.

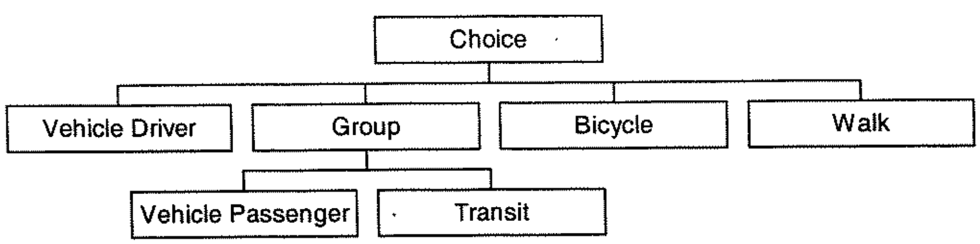

Figure 7: Existing Home-Based School -- High School Mode Choice Model Structure

The nesting coefficient is as follows:

- Group Nest Theta = 0.2583

The Vehicle Drive and Vehicle Passenger modes will be altered as part of the I-680 Value Pricing Study. The existing Vehicle Driver and Vehicle Passenger are shown below in Equations 53 and 54.

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[2] *I-680 Value Pricing Study: Travel Demand Modeling Validation*, Technical Memorandum prepared by Parsons Brinckerhoff for Caltrans and Alameda Congestion Management Authority, March 2002.

$$U_{VD} = \beta_{VD} + \beta_{IVTT} \cdot IVTT + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln((COST - PARKCST)/VOCC) + \beta_{CVHHVD} \cdot VHH(I) + \beta_{PHH} \cdot PHH(I)$$

Equation 30: Existing Vehicle Driver Mode Utility Equation

$$U_{VP} = \beta_{VP} + \beta_{IVTT} \cdot (IVTT - S2PEN) + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln((2 \cdot COST - PARKCST)/VOCC) + \beta_{VHHVP} \cdot VHH(I)$$

Equation 31: Existing Vehicle Passenger Mode Utility Equation

The proposed structure for the High School model is shown in Figure 8. The Vehicle Driver mode is replaced with the Drive Alone, Shared Ride 2, and Shared Ride 3+ modes, which are then segmented by Toll and No Toll sub-modes. The Vehicle Passenger mode is unchanged (the drivers of these passengers are captured in the Vehicle Driver modes as well as the Home-based Other purpose for those students who are dropped off). Such a segmentation is required to properly assign each of the Shared Ride modes, because they have different restrictions on where they can travel.

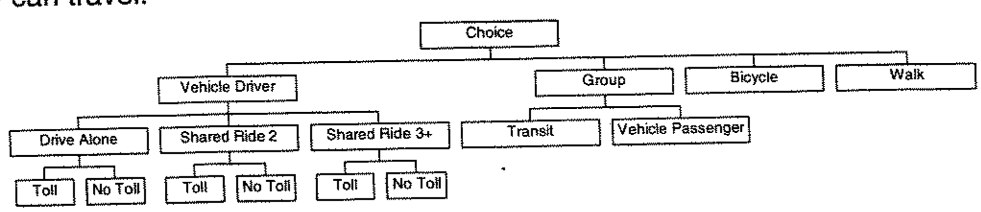

Figure 8: Proposed Home-Based School -- High School Mode Choice Model Structure

The following nesting coefficients would be used in such a model structure:

- Group Nest Theta = 0.2853
- Vehicle Driver Theta = 1.0000
- Drive Alone Toll/No Toll Nest Theta = 1.000
- Shared Ride 2 Toll/No Toll Nest Theta = 0.823
- Shared Ride 3+ Toll/No Toll Nest Theta = 0.783

The Toll/No Toll nesting coefficients are again taken from the Houston-Galveston Home-based Work model estimates. Worker and student behavior is often found to be similar in mode choice, and as a result, the nesting coefficients can be considered reasonable.

As in the previous model applications, the application program will read an additional level-of-service matrix. Such a matrix would contain the following tables:

- Drive Alone Toll in-vehicle travel time
- Drive Alone Toll cost (Toll cost)
- Drive Alone Toll operating cost
- Drive Alone No Toll in-vehicle travel time

- Drive Alone No Toll cost
- Shared Ride 2 Toll in-vehicle travel time
- Shared Ride 2 Toll cost (Toll cost)
- Shared Ride 2 Toll operating cost
- Shared Ride 2 No Toll in-vehicle travel time
- Shared Ride 2 No Toll cost
- Shared Ride 3+ Toll in-vehicle travel time
- Shared Ride 3+ Toll cost (Toll cost)
- Shared Ride 3+ Toll operating cost
- Shared Ride 3+ No Toll in-vehicle travel time
- Shared Ride 3+ No Toll cost

The application will also output a total of 14 tables. The Vehicle Driver mode is now the sum of the Drive Alone, Shared Ride 2, and Shared Ride 3+ modes. When assigned, these person trips are assumed to represent one vehicle, regardless of occupancy. The output trip tables are as follows:

- Vehicle Driver
- Vehicle Passenger
- Transit
- Bicycle
- Walk
- Drive Alone (new)
- Shared Ride 2 (new)
- Shared Ride 3+ (new)
- Drive Alone Toll (new)
- Drive Alone No Toll (new)
- Shared Ride 2 Toll (new)
- Shared Ride 2 No Toll (new)
- Shared Ride 3+ Toll (new)
- Shared Ride 3+ No Toll (new)

The proposed Toll/No Toll equations are shown in Equations 32 – 37. A few assumptions are required to fully segment the Vehicle Driver mode into the Drive Alone and Shared Ride modes. The following assumptions are made:

- Drive Alone Occupancy = 1.0
- Shared Ride 2 Time Penalty = 5.0 minutes (as in other trip purposes)
- Shared Ride 2 Occupancy = 2.0

- Shared Ride 3+ Time Penalty = 7.0 minutes (as in other trip purposes)
- Shared Ride 3+ Occupancy = 3.5 (as in other trip purposes)

The new model coefficients are shown in Table 10. Again, a β_B value is added to the No Toll equations only when the Toll modes are available.

$$U_{DANT} = \beta_{DANT} + \beta_{IVTT} \cdot IVTT_{NT} + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln((COST_{NT} - PARKCST)/1.0) \\ + \beta_{CVHHVD} \cdot VHH(I) + \beta_{PHH} \cdot PHH(I) + (\beta_B)$$

Equation 32: Proposed Drive Alone No Toll Mode Utility Equation

$$U_{DAT} = \beta_{DAT} + \beta_{IVTT} \cdot IVTT_T + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln((COST_T + TOLL - PARKCST)/1.0) \\ + \beta_{CVHHVD} \cdot VHH(I) + \beta_{PHH} \cdot PHH(I) + \beta_B$$

Equation 33: Proposed Drive Alone Toll Mode Utility Equation

$$U_{S2NT} = \beta_{S2NT} + \beta_{IVTT} \cdot (IVTT_{NT} - S2PEN) + \beta_{OVTT} \cdot OVT \\ + \beta_{LNCOST} \cdot \ln((2 \cdot COST_{NT} - PARKCST)/2.0) + \beta_{VHHVD} \cdot VHH(I) + \beta_{PHH} \cdot PHH(I) + (\beta_B)$$

Equation 34: Proposed Shared Ride 2 No Toll Mode Utility Equation

$$U_{S2T} = \beta_{S2T} + \beta_{IVTT} \cdot (IVTT_T - S2PEN) + \beta_{OVTT} \cdot OVT \\ + \beta_{LNCOST} \cdot \ln((2 \cdot COST_T + TOLL - PARKCST)/2.0) + \beta_{VHHVD} \cdot VHH(I) + \beta_{PHH} \cdot PHH(I) + \beta_B$$

Equation 35: Proposed Shared Ride 2 Toll Mode Utility Equation

$$U_{S3NT} = \beta_{S3NT} + \beta_{IVTT} \cdot (IVTT_{NT} - S3PEN) + \beta_{OVTT} \cdot OVT \\ + \beta_{LNCOST} \cdot \ln((3.5 \cdot COST_{NT} - PARKCST)/3.5) + \beta_{VHHVD} \cdot VHH(I) + \beta_{PHH} \cdot PHH(I) + (\beta_B)$$

Equation 36: Proposed Shared Ride 3+ No Toll Mode Utility Equation

$$U_{S3T} = \beta_{S3T} + \beta_{IVTT} \cdot (IVTT_T - S3PEN) + \beta_{OVTT} \cdot OVT \\ + \beta_{LNCOST} \cdot \ln((3.5 \cdot COST_T + TOLL - PARKCST)/3.5) + \beta_{VHHVD} \cdot VHH(I) \\ + \beta_{PHH} \cdot PHH(I) + \beta_B$$

Equation 37: Proposed Shared Ride 3+ Toll Mode Utility Equation

The LogSum variable is then used to calculate the composite Drive Alone and Shared Ride modes (see Equations 7 and 8).

Table 10: Proposed Toll Model Coefficients

Coefficient	Drive Alone	Shared Ride 2	Shared Ride 3+
β_B	-0.6900	-0.6878	-0.6369
Initial Minimum Time Savings (may change during testing)	0.10 Minutes	0.10 Minutes	0.10 Minutes

β_B was calibrated using all zone-to-zone pairs because no High School Trips were located in the existing I-680 corridor.

HOME-BASED SCHOOL – COLLEGE

The Home-Based College model is highly similar to the High School model only with a different nesting structure. The College structure places all the motorized modes in a separate nest. The existing structure is shown in Figure 9.

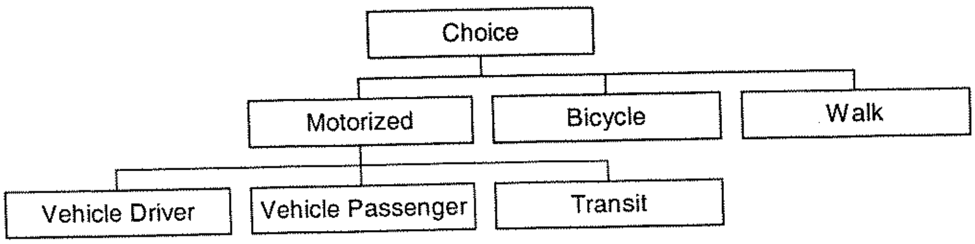

Figure 9: Existing Home-Based School -- College Mode Choice Model Structure

The nesting coefficient is as follows:

- Motorized Nest Theta = 0.5302

Again, the Vehicle Driver mode will be altered as part of this Study. The existing Vehicle Driver and Vehicle Passenger utility equations are shown in Equations 38 and 39.

$$\begin{aligned} U_{VD} &= \beta_{VD} + \beta_{IVTT} \cdot IVTT + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln((COST - PARKCST)/VOCC) \\ &+ \beta_{VHH} \cdot VHH(I) + \beta_{PHH} \cdot PHH + \beta_{LNRESDI} \cdot LNRESDI(I) \end{aligned}$$

Equation 38: Existing Vehicle Driver Mode Utility Equation

$$\begin{aligned} U_{VP} &= \beta_{VP} + \beta_{IVTT} \cdot (IVTT - S2PEN) + \beta_{OVTT} \cdot OVT \\ &+ \beta_{LNCOST} \cdot \ln((2 \cdot COST - PARKCST)/VOCC) + \beta_{VHH} \cdot VHH(I) \end{aligned}$$

Equation 39: Existing Vehicle Passenger Mode Utility Equation

The proposed structure for the College model is shown in Figure 10. The Vehicle Driver and Vehicle Passenger modes will be converted to Drive Alone, Shared Ride 2, and Shared Ride 3+ modes, segmented by Toll and No Toll. This model structure eliminates the Vehicle Passenger mode; implicitly assuming all Home-based College auto person trips make a vehicle trip (this assumption was not held in the previous formulation).

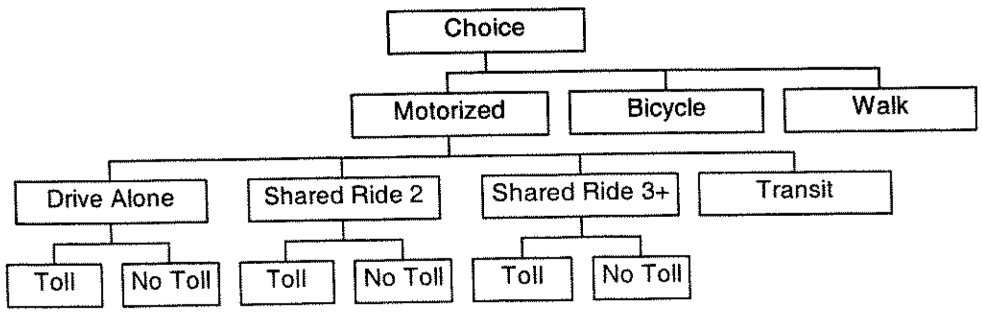

Figure 10: Proposed Home-Based School -- College Mode Choice Model Structure

The following nesting coefficients would be used in such a model structure:

- Motorized Nest Theta = 0.5302
- Drive Alone Toll/No Toll Nest Theta = 1.000
- Shared Ride 2 Toll/No Toll Nest Theta = 0.823
- Shared Ride 3+ Toll/No Toll Nest Theta = 0.783

Again, the Houston nesting coefficients are transferred to the College Model. This transfer is highly reasonable as Home-based Work and Home-based College travel is highly similar.

As in the High School model, the application program will read an additional level-of-service matrix. For the College model, the level-of-service matrix will contain identical tables as the High School model. The application will output 12 trip tables – the High School output save Vehicle Driver and Vehicle Passenger.

The proposed Drive Alone and Shared Ride utility equations are shown in Equations 40 – 45. As in the High School model, a few assumptions had to be made to accommodate the new modes in the model structure. The assumptions in the College model are identical to those in the High School model, and are shown below:

- Drive Alone Occupancy = 1.0
- Shared Ride 2 Time Penalty = 5.0 minutes (as in other trip purposes)
- Shared Ride 2 Occupancy = 2.0
- Shared Ride 3+ Time Penalty = 7.0 minutes (as in other trip purposes)
- Shared Ride 3+ Occupancy = 3.5 (as in other trip purposes)

The existing Shared Ride 2 No Toll and Shared Ride 3+ No Toll Utility equations will be identical to the existing Vehicle Passenger equation. The new model coefficients are shown in Table 11.

$$U_{DANT} = \beta_{DANT} + \beta_{IVTT} \cdot IVTT_{NT} + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln((COST_{NT} - PARKCST)/1.0)$$
$$+ \beta_{VHH} \cdot VHH(I) + \beta_{PHH} \cdot PHH + \beta_{LNRESDI} \cdot LNRESDI(I) + (\beta_B)$$

Equation 40: Proposed Drive Alone No Toll Mode Utility Equation

$$U_{DAT} = \beta_{DAT} + \beta_{IVTT} \cdot IVTT_T + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln((COST_T + TOLL - PARKCST)/1.0) + \beta_{VHH} \cdot VHH(I) + \beta_{PHH} \cdot PHH + \beta_{LNRESDI} \cdot LNRESDI(I) + \beta_B$$

Equation 41: Proposed Drive Alone Toll Mode Utility Equation

$$U_{S2NT} = \beta_{S2NT} + \beta_{IVTT} \cdot (IVTT_{NT} - S2PEN) + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln((2 \cdot COST_{NT} - PARKCST)/2.0) + \beta_{VHH} \cdot VHH(I) + (\beta_B)$$

Equation 42: Proposed Shared Ride 2 No Toll Utility Equation

$$U_{S2T} = \beta_{S2T} + \beta_{IVTT} \cdot (IVTT_T - S2PEN) + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln((2 \cdot COST_T + TOLL - PARKCST)/2.0) + \beta_{VHH} \cdot VHH(I) + \beta_B$$

Equation 43: Proposed Shared Ride 2 Toll Utility Equation

$$U_{S3NT} = \beta_{S3NT} + \beta_{IVTT} \cdot (IVTT_{NT} - S3PEN) + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln((3.5 \cdot COST_{NT} - PARKCST)/3.5) + \beta_{VHH} \cdot VHH(I) + (\beta_B)$$

Equation 44: Proposed Shared Ride 3+ No Toll Utility Equation

$$U_{S3T} = \beta_{S3T} + \beta_{IVTT} \cdot (IVTT_T - S3PEN) + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln((3.5 \cdot COST_T + TOLL - PARKCST)/3.5) + \beta_{VHH} \cdot VHH(I) + \beta_B$$

Equation 45: Proposed Shared Ride 3+ Toll Utility Equation

Table 11: Proposed Toll Model Coefficients

Coefficient	Drive Alone	Shared Ride 2	Shared Ride 3+
β_B	-0.4133	-0.3283	-0.3164
Initial Minimum Time Savings (may change during testing)	0.10 Minutes	0.10 Minutes	0.10 Minutes

NON-HOME-BASED

The Non-Home-Based model has an identical structure to the Home-Based College purpose. The existing model structure is shown in Figure 11.

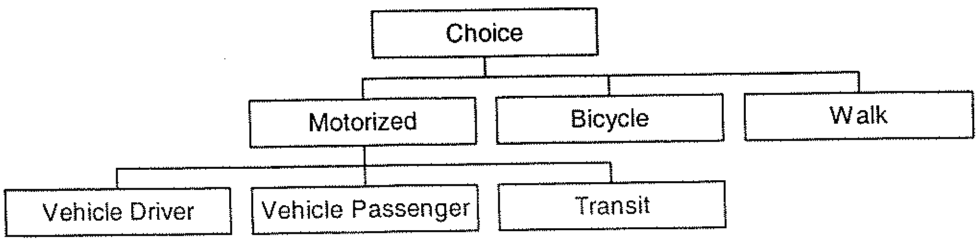

Figure 11: Existing Non-Home-Based Mode Choice Model Structure

The motorized nesting coefficient is as follows:

- Motorized Nest Theta = 0.9144

The Vehicle Driver mode will be altered as part of the I-680 Value Pricing Study. The existing utility equation for the Vehicle Driver and Vehicle Passenger modes are shown in Equations 46 and 47. The Non-Home-Based model is segmented by time period – Peak and Off-Peak – and the utility equations hold for both.

$$\begin{aligned} U_{VD} &= \beta_{VD} + \beta_{IVTT} \cdot IVTT + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln(COST / VOCC) \\ &\quad + \beta_{AREADND} \cdot AREADEN(I) \end{aligned}$$

Equation 46: Existing Vehicle Driver Mode Utility Equation

$$U_{VP} = \beta_{VP} + \beta_{IVTT} \cdot IVTT + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln(COST / VOCCVP)$$

Equation 47: Existing Vehicle Passenger Mode Utility Equation

The proposed modifications for the Non-Home-Based model are identical to those suggested for the Home-Based College model. The Vehicle Driver mode will be replaced with the Drive Alone mode, segmented by Toll and No Toll sub-modes, and the Vehicle Passenger mode will be replaced with the Shared Ride 2 and Shared Ride 3+ modes, both of which will be segmented by Toll and No Toll. The proposed model structure is shown in Figure 12.

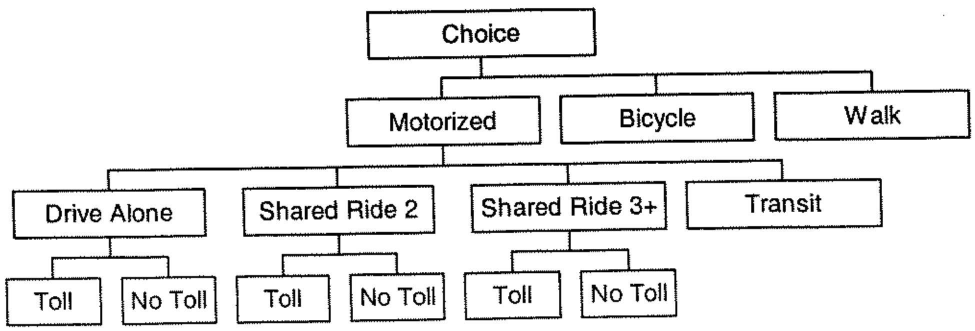

Figure 12: Proposed Non-Home-Based Mode Choice Model Structure

The following nesting coefficients would be used in such a model structure:

- Motorized Nest Theta = 0.9144
- Drive Alone Toll/No Toll Nest Theta = 1.000
- Shared Ride 2 Toll/No Toll Nest Theta = 0.823
- Shared Ride 3+ Toll/No Toll Nest Theta = 0.783

In an absence of other data, the Houston model estimates will be transferred to the Non-home-based model.

Because the Non-Home-Based model performs mode choice for both the Peak and Off-Peak time periods, two additional level-of-service matrices need to be read in by the application program. Each of these matrices will have the following tables:

- Drive Alone Toll in-vehicle travel time
- Drive Alone Toll cost (Toll cost)
- Drive Alone Toll operating cost
- Drive Alone No Toll in-vehicle travel time
- Drive Alone No Toll cost
- Shared Ride 2 Toll in-vehicle travel time
- Shared Ride 2 Toll cost (Toll cost)
- Shared Ride 2 Toll operating cost
- Shared Ride 2 No Toll in-vehicle travel time
- Shared Ride 2 No Toll cost
- Shared Ride 3+ Toll in-vehicle travel time
- Shared Ride 3+ Toll cost (Toll cost)
- Shared Ride 3+ Toll operating cost
- Shared Ride 3+ No Toll in-vehicle travel time
- Shared Ride 3+ No Toll cost

A total of 13 trip tables will be output by the application program. Vehicle Driver and Vehicle Passenger mode trip tables are not output, as these modes are not present in the proposed model structure. Although the model is applied separately for the Peak and Off-Peak periods, the model produces daily trip tables for all modes other than Transit. The output trip tables are as follows:

- Transit – Peak
- Transit – Off-Peak
- Bicycle
- Walk
- Drive Alone (new)
- Shared Ride 2 (new)
- Shared Ride 3+ (new)
- Drive Alone Toll (new)
- Drive Alone No Toll (new)
- Shared Ride 2 Toll (new)
- Shared Ride 2 No Toll (new)
- Shared Ride 3+ Toll (new)
- Shared Ride 3+ No Toll (new)

The proposed utility equations for the Drive Alone and Shared Ride modes are shown in Equations 48 – 53. As in the School models, a few assumptions had to be made to properly apply the new modes. The assumptions for the Non-Home-Based models are as follows:

- Drive Alone Occupancy = 1.0
- Shared Ride 2 Occupancy = 2.0
- Shared Ride 3+ Occupancy = 3.5

The occupancies are used to divide the cost of the mode. In the previous model structure, an occupancy of 1.254 was used for the Vehicle Driver mode and 2.000 for the Vehicle Passenger mode.

The Drive Alone No Toll utility equation is identical to the existing Vehicle Driver utility equation and the Shared Ride 2 and 3+ No Toll utility equations are identical, other than the differences listed above, to the existing Vehicle Passenger utility equation. The Toll sub-mode equations are the same for the Peak and Off-Peak periods.

$$U_{DANT} = \beta_{DANT} + \beta_{IVTT} \cdot IVTT_{NT} + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln(COST_{NT}/1.0)$$
$$+ \beta_{AREADND} \cdot AREADEN(I) + (\beta_B)$$

Equation 48: Proposed Drive Alone No Toll Mode Utility Equation

$$U_{DAT} = \beta_{DAT} + \beta_{IVTT} \cdot IVTT_T + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln((COST_T + TOLL)/1.0) + \beta_{AREADND} \cdot AREADEN(I) + \beta_B$$

Equation 49: Proposed Drive Alone Toll Mode Utility Equation

$$U_{S2NT} = \beta_{S2NT} + \beta_{IVTT} \cdot IVTT_{NT} + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln(COST_{NT}/2.0) + (\beta_B)$$

Equation 50: Proposed Shared Ride 2 No Toll Mode Utility Equation

$$U_{S2T} = \beta_{S2T} + \beta_{IVTT} \cdot IVTT_T + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln((COST_T + TOLL)/2.0) + \beta_B$$

Equation 51: Proposed Shared Ride 2 Toll Mode Utility Equation

$$U_{S3NT} = \beta_{S3NT} + \beta_{IVTT} \cdot IVTT_{NT} + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln(COST_{NT}/3.5) + (\beta_B)$$

Equation 52: Proposed Shared Ride 3+ No Toll Mode Utility Equation

$$U_{S3T} = \beta_{S3T} + \beta_{IVTT} \cdot IVTT_T + \beta_{OVTT} \cdot OVT + \beta_{LNCOST} \cdot \ln((COST_T + TOLL)/3.5) + \beta_B$$

Equation 53: Proposed Shared Ride 3+ Toll Mode Utility Equation

Table 12: Proposed Toll Model Coefficients

Coefficient	Drive Alone	Shared Ride 2	Shared Ride 3+
β_B	-0.1476	-0.0337	0.0000
Initial Minimum Time Savings (may change during testing)	0.10 Minutes	0.10 Minutes	0.10 Minutes

INTERNAL/EXTERNAL

The existing MTC model estimates external-to-internal, external-to-external, and internal-to-external trips for the Drive Alone, Shared Ride 2, and Shared Ride 3+ modes. Because of the volume, and proximity to our corridor, of these trips, a mode split model is needed to segment the trips into Toll and No Toll modes. Without such a split, the internal/external trips would either be allowed to travel on the Toll lanes (potentially filling them up) or not allowed to travel on the Toll lanes (an improbable assumption).

As the MTC Region is quite expansive, it can be assumed that the majority of internal/external trips are not making a daily round trip. Rather, most are probably passing through the region. For this reason, aspects of the Non-home-based models are proposed to split the primary auto modes into Toll and No Toll sub-modes.

A simple logit model that considers only the travel time and travel cost, while in the MTC region, is proposed. The in-vehicle travel time (IVTT) and cost coefficients can be taken from the Non-home-based mode choice model.

The Drive Alone, Shared Ride 2, and Shared Ride 3+ Utility equations, for the Toll and No Toll modes, are shown in the following equations:

$$U_{DAT} = (\beta_{IVTT} \cdot IVTT_T + \beta_{LNCOST} \cdot \ln(COST_T + TOLL)) / \theta_{DA}$$

Equation 54: Internal/External Drive Alone Toll Utility Equation

$$U_{DANT} = (\beta_{IVTT} \cdot IVTT_{NT} + \beta_{LNCOST} \cdot \ln(COST_{NT})) / \theta_{DA}$$

Equation 55: Internal/External Drive Alone No Toll Utility Equation

$$U_{SR2T} = (\beta_{IVTT} \cdot IVTT_T + \beta_{LNCOST} \cdot \ln((COST_T + TOLL) / 2.0)) / \theta_{SR2}$$

Equation 56: Internal/External Shared Ride 2 Toll Utility Equation

$$U_{SR2NT} = (\beta_{IVTT} \cdot IVTT_{NT} + \beta_{LNCOST} \cdot \ln(COST_{NT} / 2.0)) / \theta_{SR2}$$

Equation 57: Internal/External Shared Ride 2 No Toll Utility Equation

$$U_{SR3T} = (\beta_{IVTT} \cdot IVTT_T + \beta_{LNCOST} \cdot \ln((COST_T + TOLL) / 3.5)) / \theta_{SR3}$$

Equation 58: Internal/External Shared Ride 3+ Toll Utility Equation

$$U_{SR3NT} = (\beta_{IVTT} \cdot IVTT_{NT} + \beta_{LNCOST} \cdot \ln(COST_{NT} / 3.5)) / \theta_{SR3}$$

Equation 59: Internal/External Shared Ride 3+ No Toll Utility Equation

The coefficients proposed for the above equations are shown below in Table 13. The nesting coefficients are transferred from the Houston Model Development work.

Table 13: Proposed Toll Model Coefficients

Coefficient	Value
β_{IVTT}	-0.0323
β_{LNCOST}	-0.9862
θ_{DA}	1.000
θ_{SR2}	0.823
θ_{SR3}	0.783
Initial Minimum Time Savings (may change during testing)	0.10 Minutes

TRUCKS

The existing MTC model estimates trips for small, medium, and combination trucks. While combination trucks are explicitly prohibited from using the Toll facility, small and medium trucks are allowed. Similar to the internal/external market segment, allowing trucks to use the Toll facility without a mode split model could dramatically increase the volume on the Toll lanes. Prohibiting the trucks from the Toll lanes may not be a realistic assumption as many drivers of small and medium trucks have a very high value of time, and as such, would be potential users of a Toll facility.

A simple logit mode split model is proposed using only travel time and travel cost. The coefficient for travel time will be taken from the Home-based Work mode choice model and the coefficient for travel cost will be adjusted such that a value of time of $25.00 (1990$) is achieved. Experience elsewhere indicates truckers typically have a high value of time, in the neighborhood of $25.00.

The mode split model will be applied to small and medium trucks to produce estimates of small truck Toll and No Toll trips as well as medium Toll and No Toll trips. Combination trucks will be prohibited from the Toll facilities.

The Toll and No Toll utility equations are shown below:

$$U_{TOLL} = (\beta_{IVTT} \cdot IVTT_T + \beta_{COST} \cdot TOLL) / \theta_{DA}$$

Equation 60: Truck Toll Utility Equation

$$U_{NOTOLL} = (\beta_{IVTT} \cdot IVTT_{NT}) / \theta_{DA}$$

Equation 61: Truck No Toll Utility Equation

The model coefficients are shown in Table 14.

Table 14: Proposed Toll Model Coefficients

Coefficient	Value
β_{IVTT}	-0.03326
β_{COST}	-0.07982
θ_{DA}	1.000
Initial Minimum Time Savings (may change during testing)	0.10 Minutes

APPENDIX A: MODIFIED CODE ARRAY STRUCTURES

Home-based Work -- Peak Period

IN(*,Num)	File	In/Out	Value
1	101-104	Input	Homebased Work Distribution (Number depends on quartile)
2	302	Input	Transit LOS -- Auto access in-vehicle time
3	303	Input	Transit LOS -- Auto access cost
4	305	Input	Transit LOS -- Walk access in-vehicle time (Not used)
5	306	Input	Transit LOS -- Walk access cost (Not used)
6	401	Input	Transit LOS -- Auto access wait time
7	402	Input	Transit LOS -- Auto access walk time
8	407	Input	Transit LOS -- Walk access wait time (Not used)
9	408	Input	Transit LOS -- Walk access walk time (Not used)
10	501	Input	Highway LOS -- Drive alone cost
11	502	Input	Highway LOS -- Drive alone time
12	503	Input	Highway LOS -- Shared Ride 2 cost
13	504	Input	Highway LOS -- Shared Ride 2 time
14	505	Input	Highway LOS -- Shared Ride 3+ cost
15	506	Input	Highway LOS -- Shared Ride 3+ time
16	601	Input	Non-Motorized Distance
17	701	Input	Walk BART wait time
18	702	Input	Walk BART walk access time
19	703	Input	Walk BART in-vehicle time
20	704	Input	Walk BART fare
21	705	Input	Walk BART submode in-vehicle time
22	706	Input	Walk Commuter Rail wait time
23	707	Input	Walk Commuter Rail walk access time
24	708	Input	Walk Commuter Rail in-vehicle time
25	709	Input	Walk Commuter Rail fare
26	710	Input	Walk Commuter Rail submode in-vehicle time
27	711	Input	Walk Light Rail wait time
28	712	Input	Walk Light Rail walk access time
29	713	Input	Walk Light Rail in-vehicle time
30	714	Input	Walk Light Rail fare
31	715	Input	Walk Light Rail submode in-vehicle time

32	716	Input	Walk Express Bus wait time
33	717	Input	Walk Express Bus walk access time
34	718	Input	Walk Express Bus in-vehicle time
35	719	Input	Walk Express Bus fare
36	720	Input	Walk Express Bus submode in-vehicle time
37	721	Input	Walk Local Bus wait time
38	722	Input	Walk Local Bus walk access time
39	723	Input	Walk Local Bus in-vehicle time
40	724	Input	Walk Local Bus fare
41	725	Input	Walk Local Bus submode in-vehicle time
42	801	Input	Drive Alone Toll time
43	802	Input	Drive Alone Toll cost (toll cost)
44	803	Input	Drive Alone Toll operating cost
45	804	Input	Drive Alone No Toll time
46	805	Input	Drive Alone No Toll operating cost
47	806	Input	Shared Ride 2 Toll time
48	807	Input	Shared Ride 2 Toll cost (toll cost)
49	808	Input	Shared Ride 2 Toll operating cost
50	809	Input	Shared Ride 2 No Toll time
51	810	Input	Shared Ride 2 No Toll cost
52	811	Input	Shared Ride 3+ Toll time
53	812	Input	Shared Ride 3+ Toll cost (toll cost)
54	813	Input	Shared Ride 3+ Toll operating cost
55	814	Input	Shared Ride 3+ No Toll time
56	815	Input	Shared Ride 3+ No Toll cost
57	816	Input	Highway Distance (Drive Alone Toll)
58	X01	Output	Drive Alone person trips (x 1000)
59	X02	Output	Shared Ride 2 person trips
60	X03	Output	Shared Ride 3+ person trips
61	X04	Output	Transit -- Walk access person trips
62	X05	Output	Transit -- Drive access person trips
63	X06	Output	Bicycle person trips
64	X07	Output	Walk Only person trips
65	X08	Output	BART -- Walk access person trips
66	X09	Output	Commuter Rail -- Walk access person trips

67	X10	Output	Light Rail -- Walk access person trips
68	X11	Output	Express Bus -- Walk access person trips
69	X12	Output	Local Bus -- Walk access person trips
70	X13	Output	Park and Ride person trips
71	X14	Output	Kiss and Ride person trips
72	X15	Output	Drive Alone Toll person trips
73	X16	Output	Drive Alone No Toll person trips
74	X17	Output	Shared Ride 2 Toll person trips
75	X18	Output	Shared Ride 2 No Toll person trips
76	X19	Output	Shared Ride 3+ Toll person trips
77	X20	Output	Shared Ride 3+ No Toll person trips

Home-based Work -- Off-Peak Period

IN(*,Num)	File	In/Out	Value
1	101-104	Input	Homebased Work Distribution (Number depends on quartile)
2	308	Input	Transit LOS --
3	309	Input	Transit LOS --
4	411	Input	Transit LOS --
5	412	Input	Transit LOS --
6	80X	Input	Auto Toll Operating Cost
7	508	Input	Highway LOS -- Auto in-vehicle time
8	601	Input	Non-Motorized Distance
9	701	Input	Walk BART wait time
10	702	Input	Walk BART walk access time
11	703	Input	Walk BART in-vehicle time
12	704	Input	Walk BART fare
13	705	Input	Walk BART submode in-vehicle time
14	706	Input	Walk Commuter Rail wait time
15	707	Input	Walk Commuter Rail walk access time
16	708	Input	Walk Commuter Rail in-vehicle time
17	709	Input	Walk Commuter Rail fare
18	710	Input	Walk Commuter Rail submode in-vehicle time
19	711	Input	Walk Light Rail wait time
20	712	Input	Walk Light Rail walk access time
21	713	Input	Walk Light Rail in-vehicle time
22	714	Input	Walk Light Rail fare
23	715	Input	Walk Light Rail submode in-vehicle time
24	716	Input	Walk Express Bus wait time
25	717	Input	Walk Express Bus walk access time
26	718	Input	Walk Express Bus in-vehicle time
27	719	Input	Walk Express Bus fare
28	720	Input	Walk Express Bus submode in-vehicle time
29	721	Input	Walk Local Bus wait time
30	722	Input	Walk Local Bus walk access time
31	723	Input	Walk Local Bus in-vehicle time

32	724	Input	Walk Local Bus fare
33	725	Input	Walk Local Bus submode in-vehicle time
34	801	Input	Drive Alone Toll time
35	802	Input	Drive Alone Toll cost (toll cost)
36	803	Input	Drive Alone Toll operating cost
37	804	Input	Drive Alone No Toll time
38	805	Input	Drive Alone No Toll operating cost
39	806	Input	Shared Ride 2 Toll time
40	807	Input	Shared Ride 2 Toll cost (toll cost)
41	808	Input	Shared Ride 2 Toll operating cost
42	809	Input	Shared Ride 2 No Toll time
43	810	Input	Shared Ride 2 No Toll cost
44	811	Input	Shared Ride 3+ Toll time
45	812	Input	Shared Ride 3+ Toll cost (toll cost)
46	813	Input	Shared Ride 3+ Toll operating cost
47	814	Input	Shared Ride 3+ No Toll time
48	815	Input	Shared Ride 3+ No Toll cost
49	816	Input	Highway Distance (Drive Alone, Toll)
50	X01	Output	Drive Alone person trips (x 1000)
51	X02	Output	Shared Ride 2 person trips
52	X03	Output	Shared Ride 3+ person trips
53	X04	Output	Transit -- Walk access person trips
54	X05	Output	Transit -- Drive access person trips
55	X06	Output	Bicycle person trips
56	X07	Output	Walk Only person trips
57	X08	Output	BART -- Walk access person trips
58	X09	Output	Commuter Rail -- Walk access person trips
59	X10	Output	Light Rail -- Walk access person trips
60	X11	Output	Express Bus -- Walk access person trips
61	X12	Output	Local Bus -- Walk access person trips
62	X13	Output	Park and Ride person trips
63	X14	Output	Kiss and Ride person trips
64	X15	Output	Drive Alone Toll person trips
65	X16	Output	Drive Alone No Toll person trips
66	X17	Output	Shared Ride 2 Toll person trips

67	X18	Output	Shared Ride 2 No Toll person trips
68	X19	Output	Shared Ride 3+ Toll person trips
69	X20	Output	Shared Ride 3+ No Toll person trips

Home-base Shop -- Peak Period

IN(*,Num)	File	In/Out	Value
1	101	Input	Input distributed trip table
2	201	Input	Drive Alone Delta (constant calibration value)
3	202	Input	Shared Ride 2 Delta
4	203	Input	Shared Ride 3+ Delta
5	204	Input	Transit Delta
6	205	Input	Bicycle Delta
7	206	Input	Walk Only Delta
8	301	Input	Transit in-vehicle time (auto ownership 1 and 2+)
9	302	Input	Transit out-of-vehicle time (auto ownership 1 and 2+)
10	303	Input	Transit fare cost (auto ownership 1 and 2+)
11	304	Input	Transit in-vehicle time (auto ownership 0)
12	305	Input	Transit out-of-vehicle time (auto ownership 0)
13	306	Input	Transit fare cost (auto ownership 0)
14	401	Input	Drive Alone cost
15	402	Input	Drive Alone in-vehicle time
16	403	Input	Shared Ride 2 cost
17	404	Input	Shared Ride 2 in-vehicle time
18	405	Input	Shared Ride 3+ cost
19	406	Input	Shared Ride 3+ in-vehicle time
20	501	Input	Bicycle/Walk distance
21	801	Input	Drive Alone Toll time
22	802	Input	Drive Alone Toll cost (toll cost)
23	803	Input	Drive Alone Toll operating cost
24	804	Input	Drive Alone No Toll time
25	805	Input	Drive Alone No Toll operating cost
26	806	Input	Shared Ride 2 Toll time
27	807	Input	Shared Ride 2 Toll cost (toll cost)
28	808	Input	Shared Ride 2 Toll operating cost
29	809	Input	Shared Ride 2 No Toll time
30	810	Input	Shared Ride 2 No Toll cost
31	811	Input	Shared Ride 3+ Toll time

32	812	Input	Shared Ride 3+ Toll cost (toll cost)
33	813	Input	Shared Ride 3+ Toll operating cost
34	814	Input	Shared Ride 3+ No Toll time
35	815	Input	Shared Ride 3+ No Toll cost
36	207	Input	Drive Alone Toll Delta
37	208	Input	Drive Alone No Toll Delta
38	209	Input	Shared Ride 2 Toll Delta
39	210	Input	Shared Ride 2 No Toll Delta
40	211	Input	Shared Ride 3+ Toll Delta
41	212	Input	Shared Ride 3+ No Toll Delta
42	816	Input	Highway Distance (Drive Alone Toll)
43	X01	Output	Drive Alone person trips (x 100)
44	X02	Output	Shared Ride 2 person trips
45	X03	Output	Shared Ride 3+ person trips
46	X04	Output	Transit -- Auto Own 0
47	X05	Output	Transit -- Auto Own 1 and 2
48	X06	Output	Bicycle person trips
49	X07	Output	Walk Only person trips
50	X15	Output	Drive Alone Toll person trips
51	X16	Output	Drive Alone No Toll person trips
52	X17	Output	Shared Ride 2 Toll person trips
53	X18	Output	Shared Ride 2 No Toll person trips
54	X19	Output	Shared Ride 3+ Toll person trips
55	X20	Output	Shared Ride 3+ No Toll person trips

Home-base Shop -- Off-Peak Period

IN(*,Num)	File	In/Out	Value
1	101	Input	Input distributed trip table
2	201	Input	Drive Alone Delta (constant calibration value)
3	202	Input	Shared Ride 2 Delta
4	203	Input	Shared Ride 3+ Delta
5	204	Input	Transit Delta
6	205	Input	Bicycle Delta
7	206	Input	Walk Only Delta
8	307	Input	Transit in-vehicle or out-vehicle time
9	308	Input	Transit in-vehicle or out-vehicle time
10	309	Input	Transit fare cost
11	407	Input	Auto cost
12	408	Input	Auto in-vehicle travel time
13	501	Input	Bicycle/Walk distance
14	801	Input	Drive Alone Toll time
15	802	Input	Drive Alone Toll cost (toll cost)
16	803	Input	Drive Alone Toll operating cost
17	804	Input	Drive Alone No Toll time
18	805	Input	Drive Alone No Toll operating cost
19	806	Input	Shared Ride 2 Toll time
20	807	Input	Shared Ride 2 Toll cost (toll cost)
21	808	Input	Shared Ride 2 Toll operating cost
22	809	Input	Shared Ride 2 No Toll time
23	810	Input	Shared Ride 2 No Toll cost
24	811	Input	Shared Ride 3+ Toll time
25	812	Input	Shared Ride 3+ Toll cost (toll cost)
26	813	Input	Shared Ride 3+ Toll operating cost
27	814	Input	Shared Ride 3+ No Toll time
28	815	Input	Shared Ride 3+ No Toll cost
29	207	Input	Drive Alone Toll Delta
30	208	Input	Drive Alone No Toll Delta
31	209	Input	Shared Ride 2 Toll Delta

32	210	Input	Shared Ride 2 No Toll Delta
33	211	Input	Shared Ride 3+ Toll Delta
34	212	Input	Shared Ride 3+ No Toll Delta
35	816	Input	Highway Distance (Drive Alone Toll)
36	X01	Output	Drive Alone person trips (x 100)
37	X02	Output	Shared Ride 2 person trips
38	X03	Output	Shared Ride 3+ person trips
39	X04	Output	Transit -- Auto Own 0
40	X05	Output	Transit -- Auto Own 1 and 2
41	X06	Output	Bicycle person trips
42	X07	Output	Walk Only person trips
43	X15	Output	Drive Alone Toll person trips
44	X16	Output	Drive Alone No Toll person trips
45	X17	Output	Shared Ride 2 Toll person trips
46	X18	Output	Shared Ride 2 No Toll person trips
47	X19	Output	Shared Ride 3+ Toll person trips
48	X20	Output	Shared Ride 3+ No Toll person trips

Home-based Soc/Rec -- Peak Period

IN(*,Num)	File	In/Out	Value
1	102	Input	Input distributed trip table
2	201	Input	Drive Alone Delta (constant calibration value)
3	202	Input	Shared Ride 2 Delta
4	203	Input	Shared Ride 3+ Delta
5	204	Input	Transit Delta
6	205	Input	Bicycle Delta
7	301	Input	Transit in-vehicle time (auto ownership 1 and 2+)
8	302	Input	Transit out-of-vehicle time (auto ownership 1 and 2+)
9	303	Input	Transit fare cost (auto ownership 1 and 2+)
10	304	Input	Transit in-vehicle time (auto ownership 0)
11	305	Input	Transit out-of-vehicle time (auto ownership 0)
12	306	Input	Transit fare cost (auto ownership 0)
13	401	Input	Drive Alone cost
14	402	Input	Drive Alone in-vehicle time
15	403	Input	Shared Ride 2 cost
16	404	Input	Shared Ride 2 in-vehicle time
17	405	Input	Shared Ride 3+ cost
18	406	Input	Shared Ride 3+ in-vehicle time
19	501	Input	Bicycle/Walk distance
20	206	Input	Walk Delta
21	801	Input	Drive Alone Toll time
22	802	Input	Drive Alone Toll cost (toll cost)
23	803	Input	Drive Alone Toll operating cost
24	804	Input	Drive Alone No Toll time
25	805	Input	Drive Alone No Toll operating cost
26	806	Input	Shared Ride 2 Toll time
27	807	Input	Shared Ride 2 Toll cost (toll cost)
28	808	Input	Shared Ride 2 Toll operating cost
29	809	Input	Shared Ride 2 No Toll time
30	810	Input	Shared Ride 2 No Toll cost
31	811	Input	Shared Ride 3+ Toll time

32	812	Input	Shared Ride 3+ Toll cost (toll cost)
33	813	Input	Shared Ride 3+ Toll operating cost
34	814	Input	Shared Ride 3+ No Toll time
35	815	Input	Shared Ride 3+ No Toll cost
36	207	Input	Drive Alone Toll Delta
37	208	Input	Drive Alone No Toll Delta
38	209	Input	Shared Ride 2 Toll Delta
39	210	Input	Shared Ride 2 No Toll Delta
40	211	Input	Shared Ride 3+ Toll Delta
41	212	Input	Shared Ride 3+ No Toll Delta
42	816	Input	Highway Distance (Drive Alone Toll)
43	X01	Output	Drive Alone person trips (x 100)
44	X02	Output	Shared Ride 2 person trips
45	X03	Output	Shared Ride 3+ person trips
46	X04	Output	Transit -- Auto Own 0
47	X05	Output	Transit -- Auto Own 1 and 2
48	X06	Output	Bicycle person trips
49	X07	Output	Walk Only person trips
50	X08	Output	Drive Alone Toll person trips
51	X09	Output	Drive Alone No Toll person trips
52	X10	Output	Shared Ride 2 Toll person trips
53	X11	Output	Shared Ride 2 No Toll person trips
54	X12	Output	Shared Ride 3+ Toll person trips
55	X13	Output	Shared Ride 3+ No Toll person trips

Home-based Soc/Rec -- Off-Peak Period

IN(*,Num)	File	In/Out	Value
1	102	Input	Input distributed trip table
2	201	Input	Drive Alone Delta (constant calibration value)
3	202	Input	Shared Ride 2 Delta
4	203	Input	Shared Ride 3+ Delta
5	204	Input	Transit Delta
6	205	Input	Bicycle Delta
7	307	Input	Transit out-vehicle time
8	308	Input	Transit in-vehicle time
9	309	Input	Transit fare cost
10	407	Input	Auto cost
11	408	Input	Auto in-vehicle travel time
12	501	Input	Bicycle/Walk distance
13	206	Input	Walk Delta
14	801	Input	Drive Alone Toll time
15	802	Input	Drive Alone Toll cost (toll cost)
16	803	Input	Drive Alone Toll operating cost
17	804	Input	Drive Alone No Toll time
18	805	Input	Drive Alone No Toll operating cost
19	806	Input	Shared Ride 2 Toll time
20	807	Input	Shared Ride 2 Toll cost (toll cost)
21	808	Input	Shared Ride 2 Toll operating cost
22	809	Input	Shared Ride 2 No Toll time
23	810	Input	Shared Ride 2 No Toll cost
24	811	Input	Shared Ride 3+ Toll time
25	812	Input	Shared Ride 3+ Toll cost (toll cost)
26	813	Input	Shared Ride 3+ Toll operating cost
27	814	Input	Shared Ride 3+ No Toll time
28	815	Input	Shared Ride 3+ No Toll cost
29	207	Input	Drive Alone Toll Delta
30	208	Input	Drive Alone No Toll Delta
31	209	Input	Shared Ride 2 Toll Delta

32	210	Input	Shared Ride 2 No Toll Delta
33	211	Input	Shared Ride 3+ Toll Delta
34	212	Input	Shared Ride 3+ No Toll Delta
35	816	Input	Highway Distance (Drive Alone Toll)
36	X01	Output	Drive Alone person trips (x 100)
37	X02	Output	Shared Ride 2 person trips
38	X03	Output	Shared Ride 3+ person trips
39	X04	Output	Transit -- Auto Own 0
40	X05	Output	Transit -- Auto Own 1 and 2
41	X06	Output	Bicycle person trips
42	X07	Output	Walk Only person trips
43	X08	Output	Drive Alone Toll person trips
44	X09	Output	Drive Alone No Toll person trips
45	X10	Output	Shared Ride 2 Toll person trips
46	X11	Output	Shared Ride 2 No Toll person trips
47	X12	Output	Shared Ride 3+ Toll person trips
48	X13	Output	Shared Ride 3+ No Toll person trips

High School Daily

IN(*,Num)	File	In/Out	Value
1	102	Input	Input distributed trip table
2	204	Input	Transit out-of-vehicle time
3	205	Input	Transit in-vehicle time
4	206	Input	Transit fare cost
5	301	Input	Drive Alone cost
6	302	Input	Drive Alone in-vehicle time
7	303	Input	Shared Ride cost
8	304	Input	Shared Ride in-vehicle time
9	401	Input	Bicycle/Walk distance
10	801	Input	Drive Alone Toll time
11	802	Input	Drive Alone Toll cost (toll cost)
12	803	Input	Drive Alone Toll operating cost
13	804	Input	Drive Alone No Toll time
14	805	Input	Drive Alone No Toll cost
15	806	Input	Shared Ride 2 Toll time
16	807	Input	Shared Ride 2 Toll cost (toll cost)
17	808	Input	Shared Ride 2 Toll operating cost
18	809	Input	Shared Ride 2 No Toll time
19	810	Input	Shared Ride 2 No Toll cost
20	811	Input	Shared Ride 3+ Toll time
21	812	Input	Shared Ride 3+ Toll cost (toll cost)
22	813	Input	Shared Ride 3+ Toll operating cost
23	814	Input	Shared Ride 3+ No Toll time
24	815	Input	Shared Ride 3+ No Toll cost
25	816	Input	Highway Distance (Drive Alone Peak)
26	X01	Output	Vehicle Driver trips
27	X02	Output	Vehicle Passenger trips
28	X03	Output	Transit person trips
29	X04	Output	Bicycle trips
30	X05	Output	Walk Only trips
31	X06	Output	Drive Alone trips

32	X07	Output	Shared Ride 2 trips
33	X08	Output	Shared Ride 3+ trips
34	X09	Output	Drive Alone Toll trips
35	X10	Output	Drive Alone No Toll trips
36	X11	Output	Shared Ride 2 Toll trips
37	X12	Output	Shared Ride 2 No Toll trips
38	X13	Output	Shared Ride 3 Toll trips
39	X14	Output	Shared Ride 3+ No Toll trips

Home-based College -- Daily

IN(*,Num)	File	In/Out	Value
1	102	Input	Input distributed trip table
2	204	Input	Transit out-of-vehicle time
3	205	Input	Transit in-vehicle time
4	206	Input	Transit fare cost
5	301	Input	Drive Alone cost
6	302	Input	Drive Alone in-vehicle time
7	303	Input	Shared Ride cost
8	304	Input	Shared Ride in-vehicle time
9	401	Input	Bicycle/Walk distance
10	801	Input	Drive Alone Toll time
11	802	Input	Drive Alone Toll cost (toll cost)
12	803	Input	Drive Alone Toll operating cost
13	804	Input	Drive Alone No Toll time
14	805	Input	Drive Alone No Toll cost
15	806	Input	Shared Ride 2 Toll time
16	807	Input	Shared Ride 2 Toll cost (toll cost)
17	808	Input	Shared Ride 2 Toll operating cost
18	809	Input	Shared Ride 2 No Toll time
19	810	Input	Shared Ride 2 No Toll cost
20	811	Input	Shared Ride 3+ Toll time
21	812	Input	Shared Ride 3+ Toll cost (toll cost)
22	813	Input	Shared Ride 3+ Toll operating cost
23	814	Input	Shared Ride 3+ No Toll time
24	815	Input	Shared Ride 3+ No Toll cost
25	816	Input	Highway Distance (Drive Alone Toll)
26	X01	Output	Vehicle Driver trips
27	X02	Output	Vehicle Passenger trips
28	X03	Output	Transit person trips
29	X04	Output	Bicycle trips
30	X05	Output	Walk Only trips
31	X06	Output	Drive Alone trips

32	X07	Output	Shared Ride 2 trips
33	X08	Output	Shared Ride 3+ trips
34	X09	Output	Drive Alone Toll trips
35	X10	Output	Drive Alone No Toll trips
36	X11	Output	Shared Ride 2 Toll trips
37	X12	Output	Shared Ride 2 No Toll trips
38	X13	Output	Shared Ride 3 Toll trips
39	X14	Output	Shared Ride 3+ No Toll trips

Non-Home-based -- Peak and Off-Peak

IN(*,Num)	File	In/Out	Value
1	103	Input	Input Distributed Trip Tables
2	201	Input	Vehicle Driver Deltas
3	202	Input	Vehicle Passenger Deltas
4	203	Input	Transit Deltas
5	204	Input	Bike Deltas
6	205	Input	Walk Deltas
7	407	Input	Peak Transit wait time
8	305	Input	Peak Transit in-vehicle time
9	306	Input	Peak Transit cost
10	408	Input	Peak Transit out-of-vehicle time
11	411	Input	Off-Peak Transit wait time
12	308	Input	Off-Peak Transit in-vehicle time
13	309	Input	Off-Peak Transit cost
14	412	Input	Off-Peak Transit out-of-vehicle time
15	501	Input	Peak Auto cost
16	502	Input	Peak Auto in-vehicle time
17	507	Input	Off-Peak Auto cost
18	508	Input	Off-Peak Auto in-vehicle time
19	601	Input	Bike/Walk distance
20	801	Input	Peak Drive Alone Toll time
21	802	Input	Peak Drive Alone Toll cost (toll cost)
22	803	Input	Peak Drive Alone Toll operating cost
23	804	Input	Peak Drive Alone No Toll time
24	805	Input	Peak Drive Alone No Toll cost
25	806	Input	Peak Shared Ride 2 Toll time
26	807	Input	Peak Shared Ride 2 Toll cost (toll cost)
27	808	Input	Peak Shared Ride 2 Toll operating cost
28	809	Input	Peak Shared Ride 2 No Toll time
29	810	Input	Peak Shared Ride 2 No Toll cost
30	811	Input	Peak Shared Ride 3+ Toll time
31	812	Input	Peak Shared Ride 3+ Toll cost (toll cost)

32	813	Input	Peak Shared Ride 3+ Toll operating cost
33	814	Input	Peak Shared Ride 3+ No Toll time
34	815	Input	Peak Shared Ride 3+ No Toll cost
35	701	Input	Off-Peak Drive Alone Toll time
36	702	Input	Off-Peak Drive Alone Toll cost (toll cost)
37	703	Input	Off-Peak Drive Alone Toll operating cost
38	704	Input	Off-Peak Drive Alone No Toll time
39	705	Input	Off-Peak Drive Alone No Toll cost
40	706	Input	Off-Peak Shared Ride 2 Toll time
41	707	Input	Off-Peak Shared Ride 2 Toll cost (toll cost)
42	708	Input	Off-Peak Shared Ride 2 Toll operating cost
43	709	Input	Off-Peak Shared Ride 2 No Toll time
44	710	Input	Off-Peak Shared Ride 2 No Toll cost
45	711	Input	Off-Peak Shared Ride 3+ Toll time
46	712	Input	Off-Peak Shared Ride 3+ Toll cost (toll cost)
47	713	Input	Off-Peak Shared Ride 3+ Toll operating cost
48	714	Input	Off-Peak Shared Ride 3+ No Toll time
49	715	Input	Off-Peak Shared Ride 3+ No Toll cost
50	206	Input	Drive Alone Deltas
51	207	Input	Shared Ride 2 Deltas
52	208	Input	Shared Ride 3+ Deltas
53	209	Input	Drive Alone Toll Deltas
54	210	Input	Drive Alone No Toll Deltas
55	211	Input	Shared Ride 2 Toll Deltas
56	212	Input	Shared Ride 2 No Toll Deltas
57	213	Input	Shared Ride 3+ Toll Deltas
58	214	Input	Shared Ride 3+ No Toll Deltas
59	816	Input	Peak Highway Distance (Drive Alone Toll)
60	716	Input	Off-Peak Highway Distance (Drive Alone Toll)
61	X01	Output	Vehicle Driver daily trips
62	X02	Output	Vehicle Passenger daily trips
63	X03	Output	Transit Peak daily trips
64	X04	Output	Transit Off-Peak daily trips
65	X05	Output	Bike daily trips
66	X06	Output	Walk daily trips

67	X07	Output	Drive Alone daily trips
68	X08	Output	Shared Ride 2 daily trips
69	X09	Output	Shared Ride 3+ daily trips
70	X10	Output	Drive Alone Toll daily trips
71	X11	Output	Drive Alone No Toll daily trips
72	X12	Output	Shared Ride 2 Toll daily trips
73	X13	Output	Shared Ride 2 No Toll daily trips
74	X14	Output	Shared Ride 3+ Toll daily trips
75	X15	Output	Shared Ride 3+ No Toll daily trips

Appendix C

Memorandum on Testing Results of Toll-Enhanced Travel Demand Model

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Appendix C

To: Emily Landin –Lowe, Caltrans
Jean Hart, Alameda CMA

From: David Ory, Parsons Brinckerhoff

Date: August 5, 2002

Subject: I-680 Value Pricing Study: Testing Results of Toll-Enhanced Travel Demand Model

As part of the I-680 Value Pricing Study, the Metropolitan Transportation Commission's (MTC) Regional Travel Demand Model was enhanced to explicitly model travelers' decisions to use a Value Toll (as opposed to a bridge toll) facility. Because no such facilities currently exist in the region, the model cannot be calibrated to observed conditions. The model can, however, be checked for reasonableness through testing. The process of testing toll choice aspects of the I-680 Demand Model is the subject of this memorandum.

The memorandum contains three sections. The first section, Testing Procedure, discusses specific details of the tests. Next, the Model Adjustment section outlines the changes made to the Demand Model as a result of testing. And the final section, Results, presents detailed summaries of the test outcome.

TESTING PROCEDURE

A test network was constructed from the 2025 base network provided by the Santa Clara Valley Transportation Authority (VTA). The test network highly resembles the Alternative 3 network provided by Caltrans. In the Southbound direction, the test network contains a single toll lane, which runs parallel to the existing I-680 general purpose lanes. The toll lane has a single access point near Route 84 and a single egress point near Calaveras Boulevard. A similar configuration holds in the Northbound direction, with a single access point near Calaveras and a single egress point near Route 84. Unlike Alternative 3, the test network will be modeled as a straight toll facility, rather than a High Occupancy Toll (HOT) facility. Meaning, no discounts will be given to high occupancy vehicles (HOVs).

The testing was carried out on the base year model (2000) as well as the forecast year (2025), using the same 2025 highway network. The model structures are identical, and the only difference are socio-economic input data, but because certain Alternatives are to be tested in the base and future year, we wanted to insure that both streams were behaving in a consistent manner.

A toll value of $7 (1990 dollars) was chosen as the base value upon which the elasticity of the toll was measured. The toll was selected at the relatively high value to insure the toll facility would operate without congestion in the 2025 tests.

ADJUSTMENTS

As testing proceeded, a number of changes and adjustments were made to various inputs and assumptions. The changes are as follows:

- Minimum Time Threshold – The model assumes only those travelers saving a minimum amount of time will consider using the toll facility. Initially, this value was set at 0.0 minutes. Such a formulation would allow any traveler who could save any amount of time to consider using the facility. We quickly realized the value had to be greater than zero because of the large number of trips who could use the I-680 corridor and the probabilistic nature of MTC's mode choice models. A probabilistic model form assigns a non-zero probability to every available option, even those options which have very little desirability. To avoid having a large number of toll users who were saving very little time using the facility, a minimum time threshold of 5 minutes was put into place. Such an assumption would only allow those travelers who have a significant benefit to consider the toll facility.
- Truck Value of Time – The initial model formulation assumed a truck value of time of $25 per hour (1990 dollars). Further information gathering revealed the average annual wage rate in the MTC Region is approximately $22 per hour. To be consistent with this value, the Truck value of time was set at 1.0 times the average wage rate, or $22 per hour.
- Internal/External (IX) Toll Model – The large number of internal/external trips in the corridor necessitated the development of a toll/no toll mode split model. The original specification of the model used the time and cost coefficients from MTC's Non-home Based Mode Choice model. Further information gathering revealed the majority of the IX trips were, in fact, work trips. As a result, the formulation was changed to utilize the Home-based Work Mode Choice coefficients.
- Internal/External (IX) Trucks – Included in the IX trip table are combination truck trips, which are not allowed on the toll facility. As a means of eliminating these trips, 8 percent of the drive alone IX trips were assumed to be trucks, and as such, prohibited from using the toll facility.
- School Trips – The Home-based High School and Home-based College Mode Choice models utilize the peak period highway networks to produce daily trips. The result of such a formulation is that High School and College trips can choose to use the toll facility for trips made throughout the day. This is in stark contrast to the other trip purposes, where only a segment of the daily trips can consider using the toll purpose (those which occur in the 'Peak' period). The result is the School and College trip purposes receive a disproportionately high number of toll trips. As a resolution, the High School and College toll trips are assigned to the non-toll network. This approach has a very minor impact on the model as very few of these trips occur in the I-680 corridor.
- Damping Mechanism – The I-680 Demand Model is applied in an iterative fashion. The assignment speeds from each iteration are fed back into the mode choice and assignment processes of the model. Depending on the input starting speeds, this process can create large oscillations from one iteration to the next. To help reduce the size of these oscillations, a method of successive averages was put into place and applied between iterations. Each iteration is averaged with all the preceding iterations to determine the travel time for the next iteration.

It should be noted that the changes mentioned above were not captured in a previous technical memorandum[1] summarizing the model form, and should be considered when reviewing the previous memorandum.

RESULTS

The primary goal in the testing was to insure the new Mode Choice models were behaving reasonably when faced with a toll/no toll choice. Further, the testing allowed the aggregate performance of the entire I-680 Demand Model to be examined.

Tables 1-3 summarize the performance of the model when applied at the base year of 2000.

Table 1 summarizes the aggregate performance of the demand model by examining the assigned highway vehicle volumes. The elasticity is relatively high at about –1.00, meaning, a 1 percent increase in the toll price will cause a 1 percent decrease in the toll volume. While this value seems high, we must remember that the toll is also relatively high at $7.00 (1990 dollars), and while the congestion in the corridor is bad, it is not overwhelmingly miserable. Table 5, which summarizes the same data during year 2025, we see the elasticity is much lower. This is a result of the congestion being much greater, thus making the toll facility a more desirable option, even with a high toll cost.

Table 2 summarizes the impact of a toll increase on the Home-based Work Mode Choice model. The Table summarizes only Home-based Work trips that use the toll facility during the Mode Choice Peak Period (which is different from the assignment peak period). Again, we see an elasticity which is rather high, near –1.00. Also, the number of toll users increases dramatically as the Income quartile increases, which is an intuitive result.

Table 3 summarizes the impact of a toll increase on the Non-work Mode Choice models. Looking first at the Home-based Shop/Other purpose, we see that the number of toll trips actually increases with an increase in the toll. The reason for this counterintuitive result is the way cost is treated in the MTC Non-Work Mode Choice Models. The Non-Work MTC Models have a logarithmic relationship with cost rather than the traditional linear relationship with cost. Such a formulation causes the value of time to be a function of the cost – meaning, the more a trip costs, the more one is willing to pay in relation to the time it takes. The formulation becomes more troublesome when the cost increases a significant amount, such as when a value toll or bridge toll is introduced. Because the number of Non-work trips using the I-680 corridor is relatively minor, the cost function was not changed. The unintuitive results show up throughout Table 3. One can see the Home-based Social/Recreation and Non-home-based trips exhibit a smaller elasticity than the Home-based Work trips in Table 2 – an unintuitive result..

Tables 4 through 6 summarize the model at the forecast year of 2025 and show identical data to Tables 1 through 3. In general, the patterns present in the 2000 results are identical to the 2025 results. For the most part, the elasticity values are generally smaller in magnitude in 2025 due to the increase in congestion in the corridor.

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[1] *Technical Memorandum: Travel Demand Modeling Program and Mode Choice Model Specifications*, To Caltrans and Alameda CMA from Parsons Brinckerhoff, April, 2002.

Table 7 summarizes the Internal/External trips in the forecast year. The table indicates the trips have an elasticity similar to Home-based Work trips. This result is expected because the IX trips are considered to be Work trips.

Table 8 summarizes the Truck trips. While combination trucks are prohibited from using the toll facility, Small and Medium trucks are permitted. The Table indicates that trucks are relatively indifferent to a toll increase. This result makes sense in that trucks typically have a high value of time.

Table 1: 2000 Facility Volume Toll Elasticy Calculations

Time Period	Travel Mode	Tolls			Toll Lane Volumes			Toll Elasticity
		Base	New	Change	Base	New	Change	
AM 2-Hour Peak	Northbound	$7.00	$8.00	$1.00	10	9	-1.0	-0.694
	Southbound	$7.00	$8.00	$1.00	1,768	1,504	-263.9	-1.044
PM 1-Hour Peak	Northbound	$7.00	$8.00	$1.00	831	727	-103.6	-0.873
	Southbound	$7.00	$8.00	$1.00	26	22	-4.0	-1.068

Table 2: 2000 Home-based Work Peak Mode Choice Model Toll Elasticity Calculations

Income Quartile	Travel Mode	Tolls			Toll Trips			Toll Elasticity
		Base	New	Change	Base	New	Change	
1	Drive Alone	$7.00	$8.00	$1.00	1,630	1,449	-181.3	-0.778
	Shared Ride 2	$7.00	$8.00	$1.00	864	714	-150.0	-1.215
	Shared Ride 3+	$7.00	$8.00	$1.00	198	168	-29.9	-1.055
	All Auto Modes	*$7.00*	*$8.00*	*$1.00*	*2,692*	*2,331*	*-361.1*	*-0.939*
2	Drive Alone	$7.00	$8.00	$1.00	5,853	5,093	-760.3	-0.909
	Shared Ride 2	$7.00	$8.00	$1.00	1,808	1,516	-292.4	-1.132
	Shared Ride 3+	$7.00	$8.00	$1.00	601	497	-104.4	-1.215
	All Auto Modes	*$7.00*	*$8.00*	*$1.00*	*8,263*	*7,106*	*-1157.1*	*-0.980*
3	Drive Alone	$7.00	$8.00	$1.00	16,414	14,327	-2087.7	-0.890
	Shared Ride 2	$7.00	$8.00	$1.00	2,749	2,307	-441.4	-1.124
	Shared Ride 3+	$7.00	$8.00	$1.00	1,114	923	-190.8	-1.199
	All Auto Modes	*$7.00*	*$8.00*	*$1.00*	*20,277*	*17,557*	*-2719.9*	*-0.939*
4	Drive Alone	$7.00	$8.00	$1.00	25,311	22,017	-3294.3	-0.911
	Shared Ride 2	$7.00	$8.00	$1.00	4,490	3,771	-719.5	-1.122
	Shared Ride 3+	$7.00	$8.00	$1.00	1,968	1,631	-336.3	-1.196
	All Auto Modes	*$7.00*	*$8.00*	*$1.00*	*31,769*	*27,419*	*-4350.1*	*-0.958*

Table 3: 2000 Non-Work Mode Choice Model Toll Elasticity Calculations

Trip Purpose	Time Period	Travel Mode	Tolls			Toll Trips			Toll Elasticity
			Base	New	Change	Base	New	Change	
Home-based Shop/Other	Peak	Drive Alone	$7.00	$8.00	$1.00	497.6	513.4	15.8	0.222
		Shared Ride 2	$7.00	$8.00	$1.00	379.0	381.5	2.6	0.047
		Shared Ride 3+	$7.00	$8.00	$1.00	146.6	147.4	0.9	0.042
		All Auto Modes	*$7.00*	*$8.00*	*$1.00*	*1,023*	*1,042*	*19.2*	*0.132*
Home-based Soc/Rec	Peak	Drive Alone	$7.00	$8.00	$1.00	120.1	113.1	-7.1	-0.411
		Shared Ride 2	$7.00	$8.00	$1.00	34.4	28.2	-6.2	-1.260
		Shared Ride 3+	$7.00	$8.00	$1.00	23.4	19.8	-3.6	-1.077
		All Auto Modes	*$7.00*	*$8.00*	*$1.00*	*178*	*161*	*-16.9*	*-0.663*
Non-Home-based	Daily	Drive Alone	$7.00	$8.00	$1.00	293.4	280.2	-13.2	-0.314
		Shared Ride 2	$7.00	$8.00	$1.00	129.6	121.9	-7.8	-0.419
		Shared Ride 3+	$7.00	$8.00	$1.00	34.1	31.7	-2.4	-0.487
		All Auto Modes	*$7.00*	*$8.00*	*$1.00*	*457*	*434*	*-23.3*	*-0.356*

Table 4: 2025 Facility Volume Toll Elasticities

Time Period	Travel Mode	Tolls			Toll Lane Volumes			Toll Elasticity
		Base	New	Change	Base	New	Change	
AM 2-Hour Peak	Northbound	$7.00	$8.00	$1.00	30	28	-2.0	-0.470
	Southbound	$7.00	$8.00	$1.00	2,631	2,494	-136.7	-0.364
PM 1-Hour Peak	Northbound	$7.00	$8.00	$1.00	1,629	1,483	-146.0	-0.628
	Southbound	$7.00	$8.00	$1.00	107	100	-6.4	-0.420

Table 5: 2025 Home-based Work Mode Choice Peak Period Trip Toll Elasticities

Income Quartile	Travel Mode	Tolls			Toll Person Trips			Toll Elasticity
		Base	New	Change	Base	New	Change	
1	Drive Alone	$7.00	$8.00	$1.00	88	81	-7.1	-0.560
	Shared Ride 2	$7.00	$8.00	$1.00	31	29	-1.9	-0.430
	Shared Ride 3+	$7.00	$8.00	$1.00	9	7	-1.8	-1.410
	All Auto Modes	*$7.00*	*$8.00*	*$1.00*	*128*	*117*	*-10.7*	*-0.586*
2	Drive Alone	$7.00	$8.00	$1.00	593	556	-37.0	-0.437
	Shared Ride 2	$7.00	$8.00	$1.00	220	203	-16.2	-0.516
	Shared Ride 3+	$7.00	$8.00	$1.00	64	60	-3.7	-0.408
	All Auto Modes	*$7.00*	*$8.00*	*$1.00*	*877*	*820*	*-56.9*	*-0.454*
3	Drive Alone	$7.00	$8.00	$1.00	2,417	2,226	-191.4	-0.554
	Shared Ride 2	$7.00	$8.00	$1.00	644	604	-40.4	-0.439
	Shared Ride 3+	$7.00	$8.00	$1.00	192	178	-13.7	-0.498
	All Auto Modes	*$7.00*	*$8.00*	*$1.00*	*3,253*	*3,008*	*-245.4*	*-0.528*
4	Drive Alone	$7.00	$8.00	$1.00	4,474	4,141	-332.9	-0.521
	Shared Ride 2	$7.00	$8.00	$1.00	923	849	-74.2	-0.563
	Shared Ride 3+	$7.00	$8.00	$1.00	497	453	-44.2	-0.622
	All Auto Modes	*$7.00*	*$8.00*	*$1.00*	*5,894*	*5,443*	*-451.2*	*-0.536*

Table 6: 2025 Non-Work Mode Choice Toll Elasticities

Trip Purpose	Time Period	Travel Mode	Tolls			Toll Person Trips			Toll Elasticity
			Base	New	Change	Base	New	Change	
Home-based Shop/Other	Peak	Drive Alone	$7.00	$8.00	$1.00	1063.3	1118.1	54.8	0.360
		Shared Ride 2	$7.00	$8.00	$1.00	936.2	1040.2	104.0	0.777
		Shared Ride 3+	$7.00	$8.00	$1.00	375.3	413.9	38.7	0.721
		All Auto Modes	*$7.00*	*$8.00*	*$1.00*	*2,375*	*2,572*	*197.4*	*0.582*
Home-based Soc/Rec	Peak	Drive Alone	$7.00	$8.00	$1.00	257.2	251.9	-5.3	-0.143
		Shared Ride 2	$7.00	$8.00	$1.00	63.6	56.2	-7.4	-0.816
		Shared Ride 3+	$7.00	$8.00	$1.00	55.0	52.6	-2.4	-0.302
		All Auto Modes	*$7.00*	*$8.00*	*$1.00*	*376*	*361*	*-15.1*	*-0.280*
Non-Home-based	Daily	Drive Alone	$7.00	$8.00	$1.00	626.5	629.4	2.9	0.033
		Shared Ride 2	$7.00	$8.00	$1.00	258.6	260.5	1.9	0.053
		Shared Ride 3+	$7.00	$8.00	$1.00	88.9	87.1	-1.8	-0.143
		All Auto Modes	*$7.00*	*$8.00*	*$1.00*	*974*	*977*	*3.0*	*0.022*

Table 7: 2025 Internal/External Mode Choice Toll Elasticities

Travel Mode	Tolls			Toll Vehicle Trips			Toll Elasticity
	Base	New	Change	Base	New	Change	
Drive Alone	$7.00	$8.00	$1.00	1,226	1,129	-97.0	-0.554
Shared Ride 2	$7.00	$8.00	$1.00	208	188	-19.6	-0.658
Shared Ride 3+	$7.00	$8.00	$1.00	37	33	-4.4	-0.830
All Auto Modes	*$7.00*	*$8.00*	*$1.00*	*1,471*	*1,350*	*-121.0*	*-0.576*

Table 8: 2025 Truck Mode Choice Toll Elasticities

Travel Mode	Tolls			Toll Vehicle Trips			Toll Elasticity
	Base	New	Change	Base	New	Change	
Small Trucks	$7.00	$8.00	$1.00	452	451	-1.0	-0.016
Medium Trucks	$7.00	$8.00	$1.00	40	39	-0.1	-0.023
Small + Medium	*$7.00*	*$8.00*	*$1.00*	*491*	*490*	*-1.2*	*-0.016*

Appendix D

Travel Demand Modeling Methodology and Alternatives Analysis

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I-680 Value Pricing Study

Travel Demand Modeling Methodology and Alternatives Analysis

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Table of Contents

List of Tables

List of Figures

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1. Introduction

This memo is intended to discuss the modeling approach and alternatives analysis of the travel demand forecasting portion of the I-680 Value Pricing Study. In addition to this document, a series of Technical Memorandums have been prepared and offer a more detailed account of various aspects of the travel demand forecasting portion of the study.

The I-680 Value Pricing Study investigates a portion of Interstate 680 located in Alameda County, California. The study area included the stretch of I-680 from the Santa Clara – Alameda County line in the south, to the I-680 – I-580 interchange in the north. In recent years, this portion of I-680 has become one of the most congested corridors in the entire San Francisco Bay Area.

The goal of the travel modeling portion of the study is to forecast the demand for a variety of possible capacity additions to I-680 in this corridor. Alternatives include High Occupancy Vehicle (HOV) and High Occupancy Toll (HOT) lanes, and the primary focus of the modeling effort was to adequately represent the demand for HOT lanes.

Section 2 of this document discusses the Modeling Approach used in the study. Section 3 briefly outlines the alternatives tested. Section 4 presents the Year 2000 model forecast results. And, Section 5 presents the Year 2025 forecast results.

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2. Modeling Approach

The primary modeling tool used in the I-680 Value Pricing Study is the Metropolitan Transportation Commission's (MTC) BAYCAST travel demand model set. The MTC model was enhanced in 2001 by the Santa Clara Valley Transportation Authority (VTA), who improved the functionality of the BAYCAST mode choice model and also performed a year 2000 validation. All the modeling work for the I-680 Study pivots off the model developed by the VTA.

As mentioned previously, the focus of the I-680 Value Pricing Study is to formally estimate the demand for a parallel High Occupancy Toll (HOT) facility in the I-680 corridor. The existing MTC/VTA model did not have the ability to explicitly model the choice between traveling on a general purpose facility and a time-savings value toll facility. The goal of this effort was to overcome this shortcoming. Please note: The term "toll" in the remainder of this document will refer to "value tolls" – a toll paid solely to provide a time savings. This is contrast to a "bridge toll", which are common in the Bay Area, and are paid to cross a natural obstruction, which is otherwise impassable.

The approach taken in the I-680 Study was to include the Toll/No Toll choice in the existing MTC/VTA Mode Choice models. This was accomplished by adding sub-nests under each of the primary auto modes (Drive Alone, Shared Ride 2, Shared Ride 3+) in the existing Nested Logit models. Figure 2.1, below, generically depicts this addition.

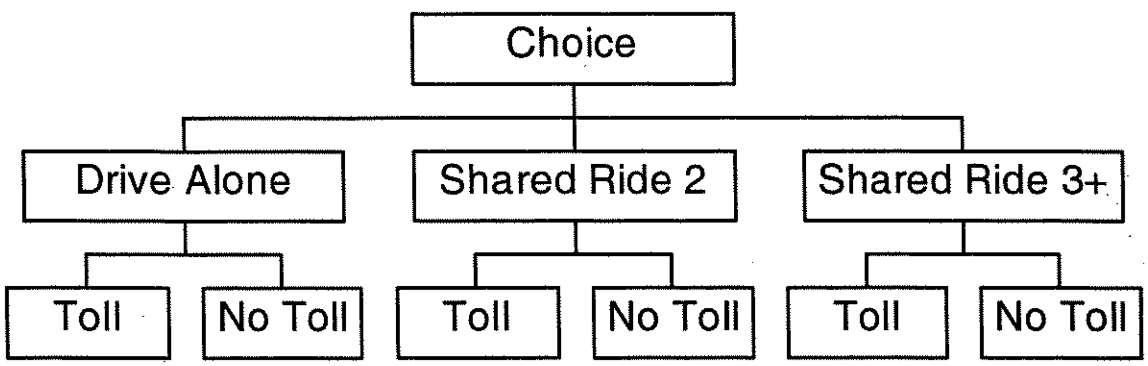

Figure 2-1: Generic Representation of Toll/No Toll Nesting Structure

As each of the MTC/VTA Mode Choice models (segmented by Trip Purpose) differ, the modifications to the nesting structures varied from Trip Purpose to Trip Purpose. Sections 2.1 through 2.4 discuss each of the trip purposes in more detail. For a complete discussion of the modifications made to the Mode Choice models, please refer to the technical memorandum *I-680 Value Pricing Study: Travel Demand Modeling Program and Mode Choice Specifications*[1].

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[1] *I-680 Value Pricing Study: Travel Demand Modeling Program and Mode Choice Specifications*, Technical Memorandum prepared by Parsons Brinckerhoff for the Alameda Congestion Management Authority and California Department of Transportation, April, 2002.

2.1 Home-based Work, Shop/Other, Social/Recreation

The Home-based Work, Home-based Shop/Other, and Home-based Social/Recreation Mode Choice models were modified in a nearly identical fashion. Though they had slightly different nesting structures, each of the trip purposes contained Drive Alone, Shared Ride 2, and Shared Ride 3+ lowest level auto nests. Toll/No Toll sub-nests were added to each of these primary auto modes.

The Toll sub-modes were included by adding an additional utility equation to represent the Toll modes. Other than the nesting coefficients, which were borrowed from work done in the Houston-Galveston Region[2], no new coefficients are included in the utility equation. The existing primary auto utility equation was used as the Toll and No Toll utility equation. The only differences in the two equations are the travel times, operating cost, and the toll cost, which is simply included in the operating cost. The Toll and No Toll equations then form a composite utility to represent the existing primary auto modes.

Because there are no "value toll" facilities currently existing in the Bay Area, no traditional re-calibration was necessary for these models. The Toll sub-mode is simply unavailable to all travelers, and thus, the No Toll sub-mode moves up the nest and becomes identical to the former primary auto mode (Drive Alone, Shared Ride 2, or Shared Ride 3+).

Another form of calibration was necessary because the addition of multiple sub-modes under an existing mode will increase the attractiveness of the existing mode in a nested logit formulation. In our application, calibration was necessary to make sure the addition of a general purpose lane and the addition of a Toll lane with a zero toll fee produced the same results – meaning, the activation of the Toll mode did not increase the desirableness of the primary auto modes if it offered no greater benefits than the No Toll modes. Without calibration, the latter example, where the Toll and the No Toll sub-modes have identical utilities, would result in a more desirable primary auto mode, and disrupt the existing mode shares. To account for this, an additional constant was added to both the Toll and No Toll sub-modes and activated only when the Toll sub-mode was available (the No Toll sub-mode is always available). These constants (a total of three for Drive Alone and Shared Ride 2 and 3+) were then calibrated by allowing the Toll mode to exist without a Toll facility in the network. A group of Origin-Destination pairs were analyzed to insure the same number of trips occurred with and without the Toll mode present. The constants are applied globally whenever the Toll sub-mode is available (different constants were not developed for different district-to-district pairs).

2.2 Home-based High School, Home-based College, and Non-home-based

The modification of the Home-based High School, College and Non-home-based Mode Choice Models was not as straightforward as the other purposes. The MTC Mode Choice Models for these trip purposes have the auto modes Vehicle Driver and Vehicle Passenger, rather than the traditional Drive Alone and Shared Ride modes. Such a formulation is problematic when assigning the auto trips, because it reveals no information about the occupancy of the vehicle. For example, all the resulting Non-

[2] *DRAFT – Home-based Work Mode Choice Model Estimation,* Houston-Galveston Area Council (H-GAC), PB Consult, March 2002.

home-based Vehicle Driver trips had to be assigned to the Drive Alone network, when certainly some fraction of the trips contained a passenger or two.

As part of the I-680 Value Pricing Study, the Mode Choice Models for these purposes were modified to represent Drive Alone, Shared Ride 2 and Shared Ride 3+ rather than Vehicle Driver and Vehicle Passenger. And, Toll/No Toll sub-nests were included under each of the new primary auto modes in a fashion identical to the trip purposes discussed in the previous section. Please refer to the *Travel Demand Modeling Program and Mode Choice Specifications* Technical Memorandum for a complete discussion of the modification of the models.

After re-specifying the models, re-calibration was required. The MTC Mode Choice models were last calibrated in 1998[3]. The 1998 calibration involved adjusting the alternative-specific constants to match observed traffic data and pivoted off mode shares developed from the 1990 Home Interview Survey.

A similar process was followed to re-calibrate the Mode Choice Models as part of the I-680 Study. New 1998 mode shares, using Drive Alone, Shared Ride 2 and 3+ rather than Vehicle Driver and Vehicle Passenger, were developed. The approach taken to develop these mode shares involved obtaining mode shares from the 1990 Home Interview Survey and applying them to the 1998 MTC Estimated trip tables. For a complete discussion on the model re-calibration effort, please refer to the memorandum *I-680 Value Pricing Study: Travel Demand Modeling Validation*[4].

After the mode shares were calibrated, additional calibration was necessary to account for the introduction of the Toll/No Toll sub-nests. A process identical to the one used for the other purposes was followed (as discussed in the previous section) and resulted in constants applied to each of the Toll/No Toll equations when the Toll mode is available.

2.3 Home-based Grade School

The final trip purpose, Home-based Grade School, was not modified as part of the I-680 Value Pricing Study. The MTC Mode Choice Model for this purpose contains only one auto mode – Vehicle Passenger. MTC structures their trip purposes such that a parent dropping their child off at elementary school is considered to be making a Home-based Other trip, and the actual student is considered to be making a Home-based Grade School trip. Because no children in Grade School are old enough to operate a motor vehicle, the Grade School trip purpose produces no vehicle trips. Thus, the introduction of a toll facility has no impact on the Grade School trips.

2.4 Highway Validation

After re-specifying and calibrating the mode choice models, the entire model stream had to be re-validated. The I-680 Modeling work pivoted directly off the VTA model which was validated for a 2000 model year. The I-680 validation aimed to replicate the statistical quality of the 2000 VTA highway validation.

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[3] *1998 Base Year Validation,* Metropolitan Transportation Commission, May 2001.

[4] *I-680 Value Pricing Study: Travel Demand Modeling Validation*, Technical Memorandum prepared by Parsons Brinckerhoff for the Alameda Congestion Management Authority and California Department of Transportation, March, 2002.

The 2000 VTA validation was performed for the 2-hour AM Peak Period. The I-680 Model set was validated for this time period, and was also validated for the 1-hour PM Peak Period. Performing a validation for both time periods allows the model to provide both AM and PM information for each of the tested alternatives.

Utilizing count data provided by Caltrans, the I-680 Model set was successfully validated for the 2-hour AM Peak Period and the 1-hour PM Peak Period. The validation achieved the same level of quality as the recent VTA highway validation. For a complete discussion of the validation process, please refer to the *Travel Demand Modeling Validation* technical memorandum.

2.5 Toll Model Testing

While the validation process provides assurance that the model stream is capable of representing base year conditions, it provided no information as to the performance of the model when faced with the introduction of a toll facility. For this reason, a formal testing of the model stream was performed.

The testing procedure involved coding a toll facility on the VTA's 2025 RTP highway network in the I-680 corridor of interest. A toll facility consisted of a single-lane facility with a single access and single egress point, which ran parallel to I-680 from Route 84 in the north and Calaveras Boulevard in the south. Different toll fees were then introduced for the facility and various performance measures were computed, including toll elasticity by trip purpose. For a complete discussion of the toll testing procedures and results, please refer to *I-680 Value Pricing Study: Travel Demand Modeling Toll Testing Results*[5].

After successfully testing the I-680 Model for both the base year of 2000 and the horizon year of 2025, the model was ready to test alternatives.

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[5] *I-680 Value Pricing Study: Travel Demand Modeling Toll Testing Results*, Technical Memorandum prepared by Parsons Brinckerhoff for the Alameda Congestion Management Authority and California Department of Transportation, August, 2002.

3. Alternative Definitions

Caltrans defined a variety of highway alternatives as part of the I-680 Value Pricing Study. Those definitions were than translated into TP+ networks and tested using the enhanced model stream. All of the network coding pivoted off the 2025 RTP network provided by the Santa Clara VTA.

The alternatives are highly specific in that the only modifications are made to the highway network on I-680, bounded by Route 84 in the north and Calaveras Boulevard in the south.

Table 3-1 summarizes the 2025 alternatives as defined by Caltrans. The first three columns are coding developed to better organize the alternatives and are not illustrative. In general, the alternatives are segmented by Primary characteristic (physical differences) and Secondary characteristics (operational differences). For example, if a given HOV facility was to be tested under an HOV 2+ scenario and an HOV3+ scenario, those would be considered to have the same Primary alternative because they have the same physical layout, but a different Secondary alternative because they have different operating characteristics. Each of the alternatives is discussed in more detail in the remainder of this section.

3.1 Alternative: Primary #1

The first alternative represents the Primary #1 – No Build scenario and includes projects already funded for the forecast year, 2025. The No Build scenario does differ from the 2000 validation network in that it contains the already approved projects.

The Primary #1 alternative contains a single lane HOV 2+ facility running parallel to the existing general purpose lanes on southbound I-680. The HOV facility begins at Route 84 and extends south to Calaveras Boulevard. The HOV lanes have access to the general purpose lanes at points near each on and off-ramp. Figures 3-1 (overview) and 3-2 (detail) depict the TP+ translation of the network. The links which are restricted to HOV2 and HOV3+ vehicles are represented with bold lines. Please note: Figure 3-1 depicts an additional lane traveling parallel to I-680 in the northbound direction as well. This lane is not "active" and is included to minimize the differences between the alternatives.

Table 3-1: Alternative Definitions

Alternative			Operating Description					
			Mainflow	HOV *1		HOT		
Geometry	Primary #	Secondary #	# of Lanes	# of Lanes	Usage	# of Lanes	Usage	Access
No Build	1	---	3	1 (SB Only)	2+	0	---	---
Geometry A	2	---	3	1	2+	0	---	---
Geometry A	3	0	3	0	---	1	3+	Beg/End
Geometry A	3	1	3	0	---	1	2+	Beg/End
Geometry A	4	0	3	0	---	1	3+	Beg/End + 1 Inter.
Geometry A	4	1	3	0	---	1	2+	Beg/End + 1 Inter.

Notes: * 1 -- All HOV lanes are assumed to have continuous access

Figure 3-1: Primary Alternative #1 Overview Network

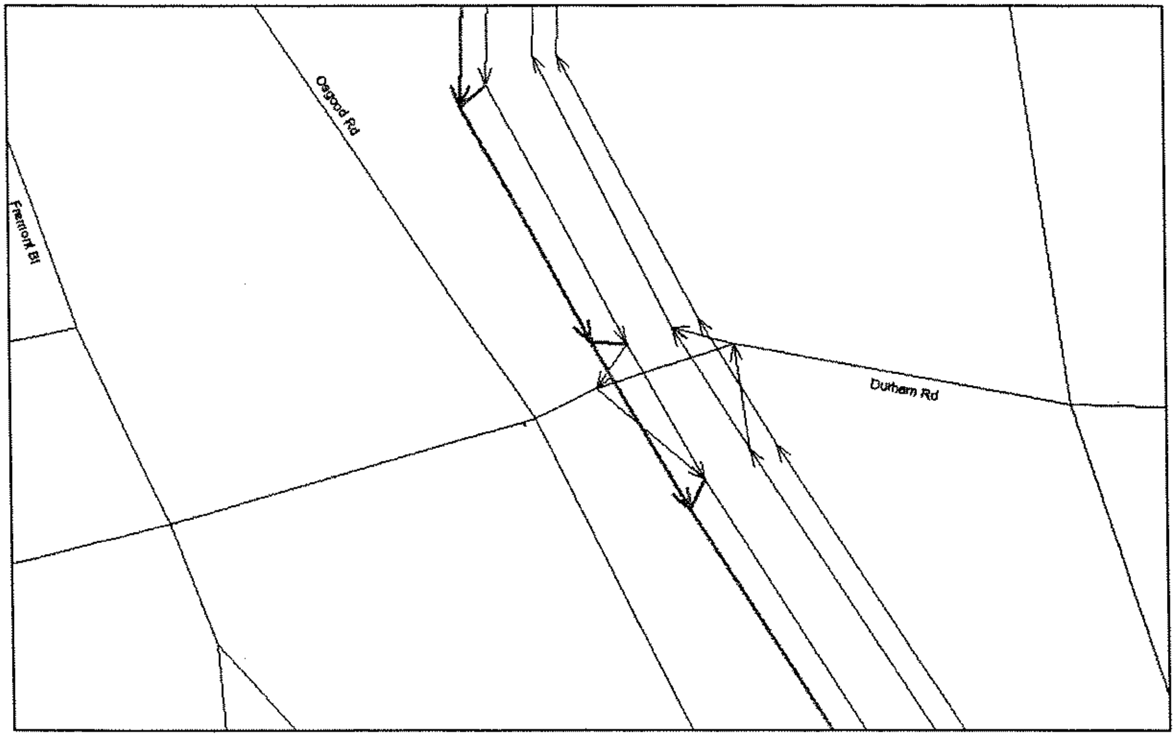

Figure 3-2: Primary Alternative #1 Detail Network

3.2 Alternative: Primary #2

The second alternative includes the southbound HOV 2+ lane in Primary #1 and adds an identical facility in the northbound direction. Both facilities have relatively continuous access to the general purpose lane and have end points at Route 84 in the north and Calaveras Boulevard in the south.

Figure 3-3 shows a detailed section of the Alternative 2 network. Again, the bold lines represent the links which are restricted to only HOV2+ and 3+ vehicles.

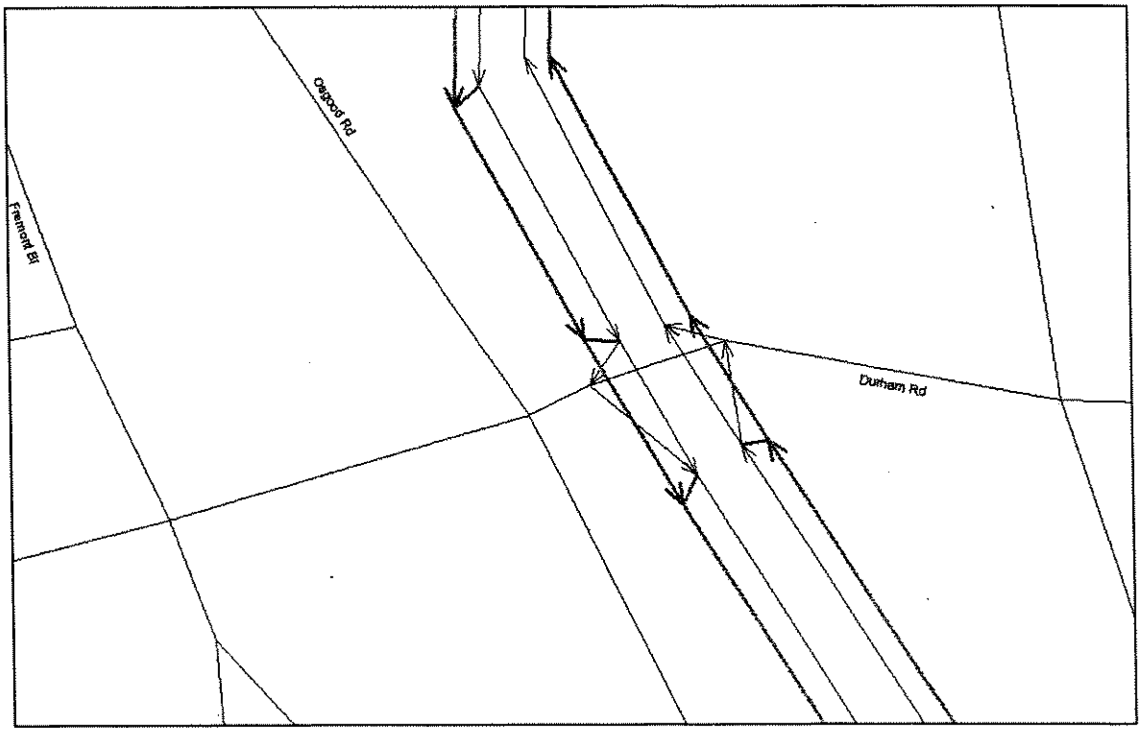

Figure 3-3: Primary Alternative #2 Detail Network

3.3 Alternative: Primary #3, Secondary #0 and Secondary #1

Alternative 3 represents a High Occupancy Toll (HOT) facility. HOV vehicles are allowed to use the facility for free, and Drive Alone vehicles are permitted to use the facility provided they pay a toll.

The only difference between the physical facility represented in Alternative 3 from Alternative 2 are the access points. Because of operational considerations, Alternative 3 limits access to the HOT facility – providing a single access and a single egress point. In this sense, the facility operates as a bypass to the general purpose lanes. In the southbound direction, users must enter the HOT facility at Route 84 and travel the distance of the corridor to the egress point at Calaveras Boulevard. The opposite is true in the northbound direction.

Figure 3-5 depicts a detail of the Alternative 3, Secondary 0 network. Notice the lack of access connectors between the general purpose lanes and the HOT lane. Also, the HOT lanes are not restricted to HOV2 and 3+ vehicles as in Alternative 2.

Secondary #0 represents the HOT3+ scenario where only HOV3+ vehicles are allowed to use the facility for free, while Single Occupancy Vehicles (SOV) and HOV2s have to pay the toll. Secondary #1 allows HOV2 and HOV3+ to use the facility for free, charging only the SOVs.

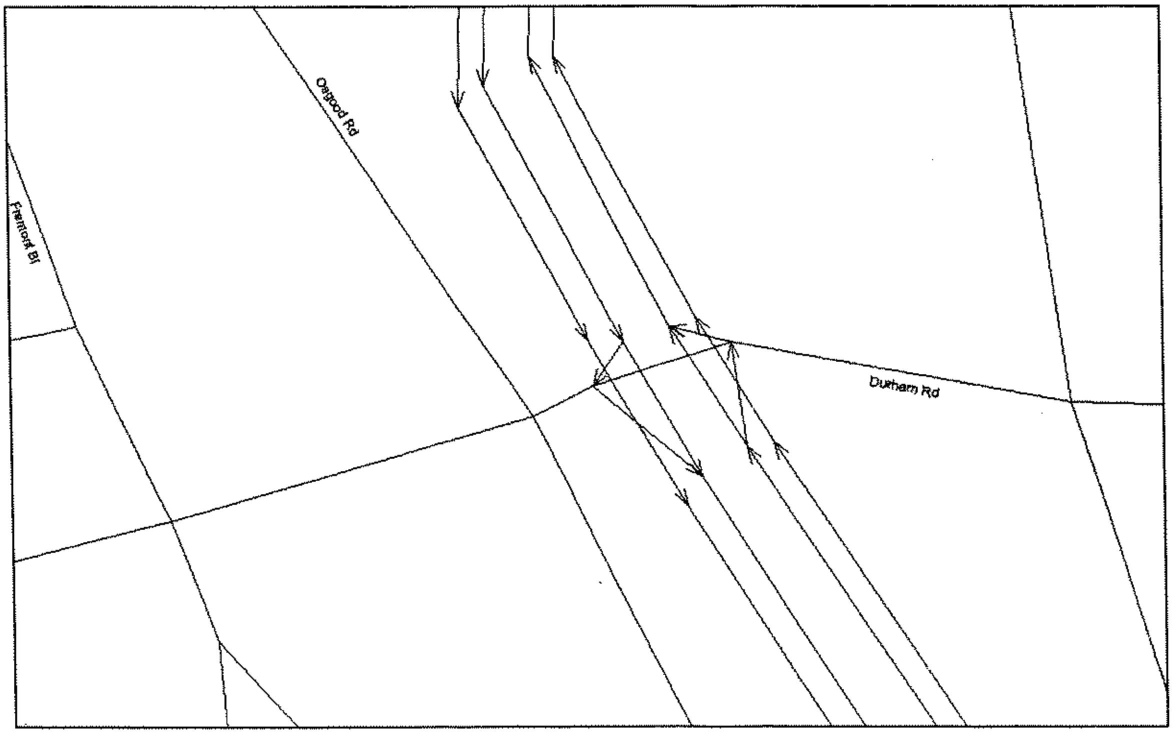

Figure 3-4: Primary Alternative #3 Detail Network

3.4 Alternative: Primary #4, Secondary #0 and Secondary #1

The fourth primary alternative pivots off Alternative 3 by adding an intermediate access/egress location near the midway point of the corridor. This allows travelers in the HOT facility to move to and from the general purpose lanes at this location.

Figure 3-6 shows the detail of the access/egress point. Notice two separate paths provide access at the intermediate location. The bold path is for HOV users and the other path is for Toll users. The separate coding allows HOV users to bypass the toll when accessing the facility.

Similar to Alternative 3, Alternative 4, Secondary 0 represents the HOT 3+ scenario and Secondary 1 represents the HOT 2+ scenario.

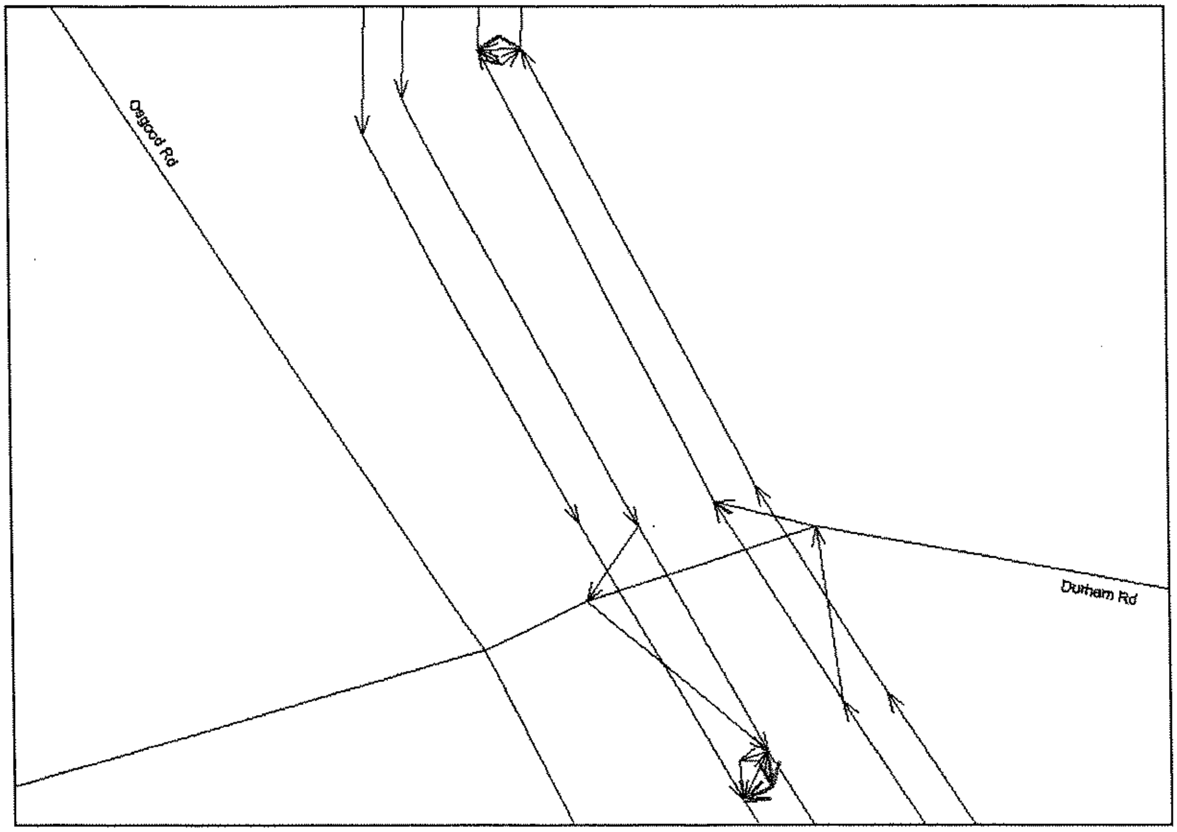

Figure 3-5: Primary Alternative #4 Detail Network

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4. Year 2000 Model Results

It is anticipated that the infrastructure improvements can be made to I-680 before the forecast year of 2025. For this reason, the 2025 Alternative Networks, as defined in the previous section, will be tested in the base Year of 2000 as well as the forecast year of 2025. This will allow two separate data points, which will provide a great deal of additional information for decision makers. It may be that the best alternative in 2025 is not the best alternative in 2005. It is hoped analyzing the alternatives for the year 2000 can aid in making those decisions.

It should be emphasized that the 2000 alternatives presented here utilize the 2025 highway networks. All the funded improvements planned for the regional highway system outside of the study corridor are included in the alternative networks.

The alternatives are analyzed strictly on the highway assignment. It is assumed that the relatively minor differences between the alternatives will have a negligible impact on the relatively negligible transit patronage currently using the corridor.

The I-680 Demand Model was developed to estimate both AM and PM Peak Period conditions. However, time and effort involved in optimizing the toll level in the HOT alternatives allowed only the AM Peak Period conditions to be completely modeled. As a result, only the AM Peak Period results in the commute direction (Southbound) will be presented here.

The AM Peak Period results are based on a 2-hour Peak Period assignment, which takes advantage of MTC's peak spreading model. As Caltrans desired one-hour volumes, a straight peaking factor of 0.577 was used to transform the 2-hour estimated volumes to 1-hour congested volumes (the travel times are not adjusted from the 2-hour estimates).

The tables in this section focus primarily on the following performance measures: travel time savings, vehicle throughput, person throughput, impact on I-880, and toll user characteristics. A separate analysis[6], performed by EcoNorthwest, summarizes the revenue generation aspect of the HOT alternatives.

For the HOT alternatives, an off-line model developed by EcoNorthwest was used to finalize the HOT-lane volumes. EcoNorthwest computed the "optimal" HOT lane volume for Alternatives 3 and 4. The I-680 Model results were then "manually" adjusted to allow the correct number of vehicles in the HOT lane, by moving vehicles between the HOT lane and the general purpose lane, and the congested times were recomputed.

4.1 Year 2000, AM Period, Southbound (Commute) Direction Model Results

Figures 4-1, 4-2, and 4-3 present a summary of vehicle throughput across all alternatives for the AM Peak Hour assignment in the Southbound (commute) direction. The tabular data for these charts can be found in Appendix A: Tabular Data. Please note: The term "Express Lane" refers to both the HOV and HOT lanes included in the alternatives.

Figure 4-1 shows the total volumes moving through the I-680 corridor in both the general purpose and Express lanes. The chart shows that the build alternatives (2 through 4)

[6] Forthcoming EcoNorthwest report

increase the volume through the corridor by approximately 1,800 vehicles – a logical result in that one Express Lane was added. The vehicular throughput is nearly identical across the build alternatives.

Figure 4-2, which depicts the impact of each of the alternatives on the vehicular volume of the general purpose lanes, demonstrates the high desirability of the corridor. Even with the additional capacity provided by the Express lanes, the general purpose lanes are largely unchanged from their base condition – which is at capacity.

Figure 4-3 provides the vehicular volumes for the Express lanes. It is important to note that the Express lane volume can be controlled by the Toll level charged to use the lane. Please see the EcoNorthwest report for more information regarding the "optimal" tolling policy used in the Study. In general, Figure 4-3 shows how in the HOV and HOT2+ scenarios (Alternatives 2, 3-0, and 4-0), the Express lane operates at around 1,200 vph. And, in the HOT3+ scenarios (Alternatives 3-1, 4-1), the Express lane operates around 900 vehicles – allowing those who are buying into the facility to receive maximum benefit.

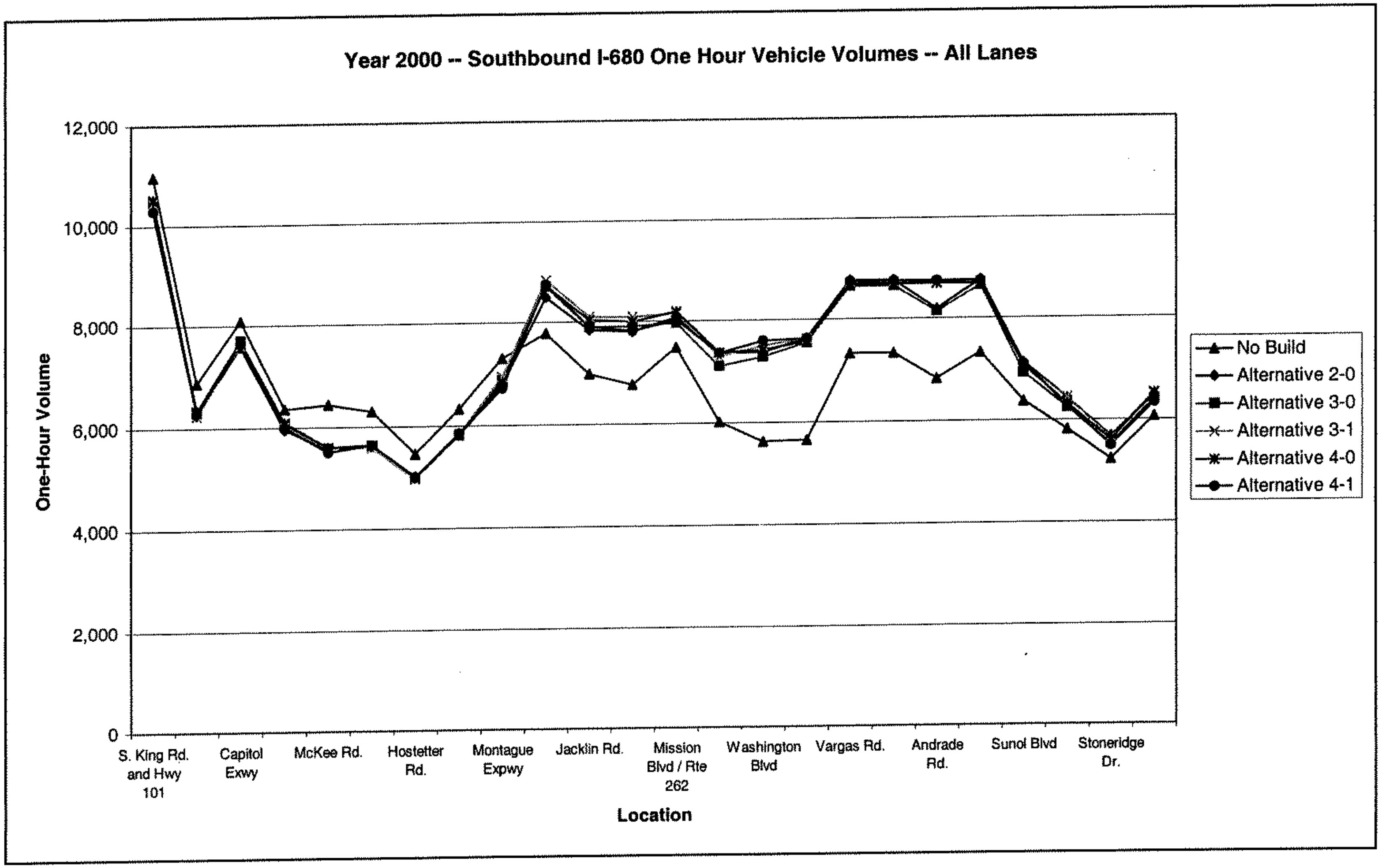

Figure 4-1: Year 2000 – Southbound I-680 One Hour Vehicle Volumes – All Lanes

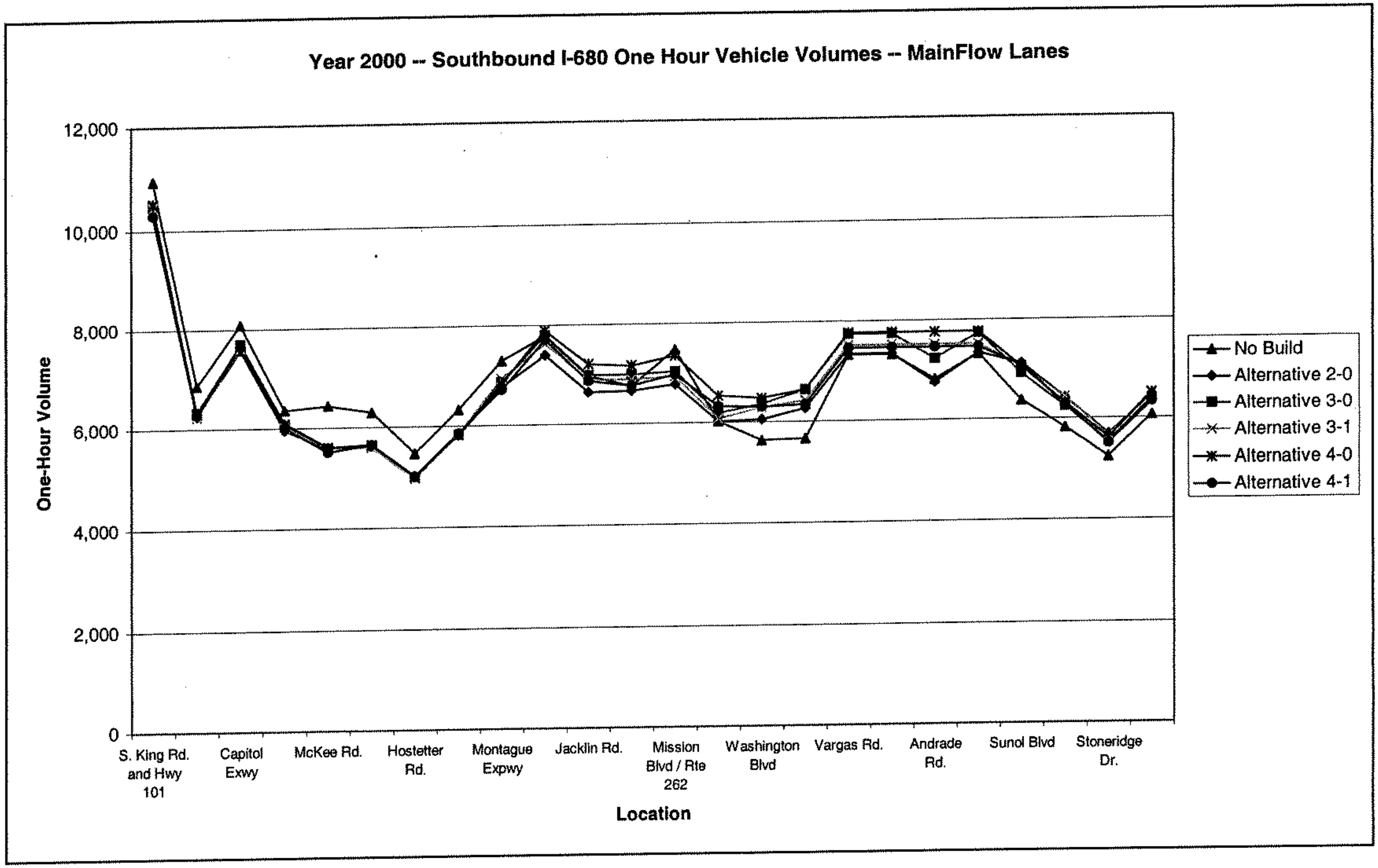

Figure 4-2: Year 2000 -- Southbound I-680 One Hour Vehicle Volumes -- General Purpose Lanes

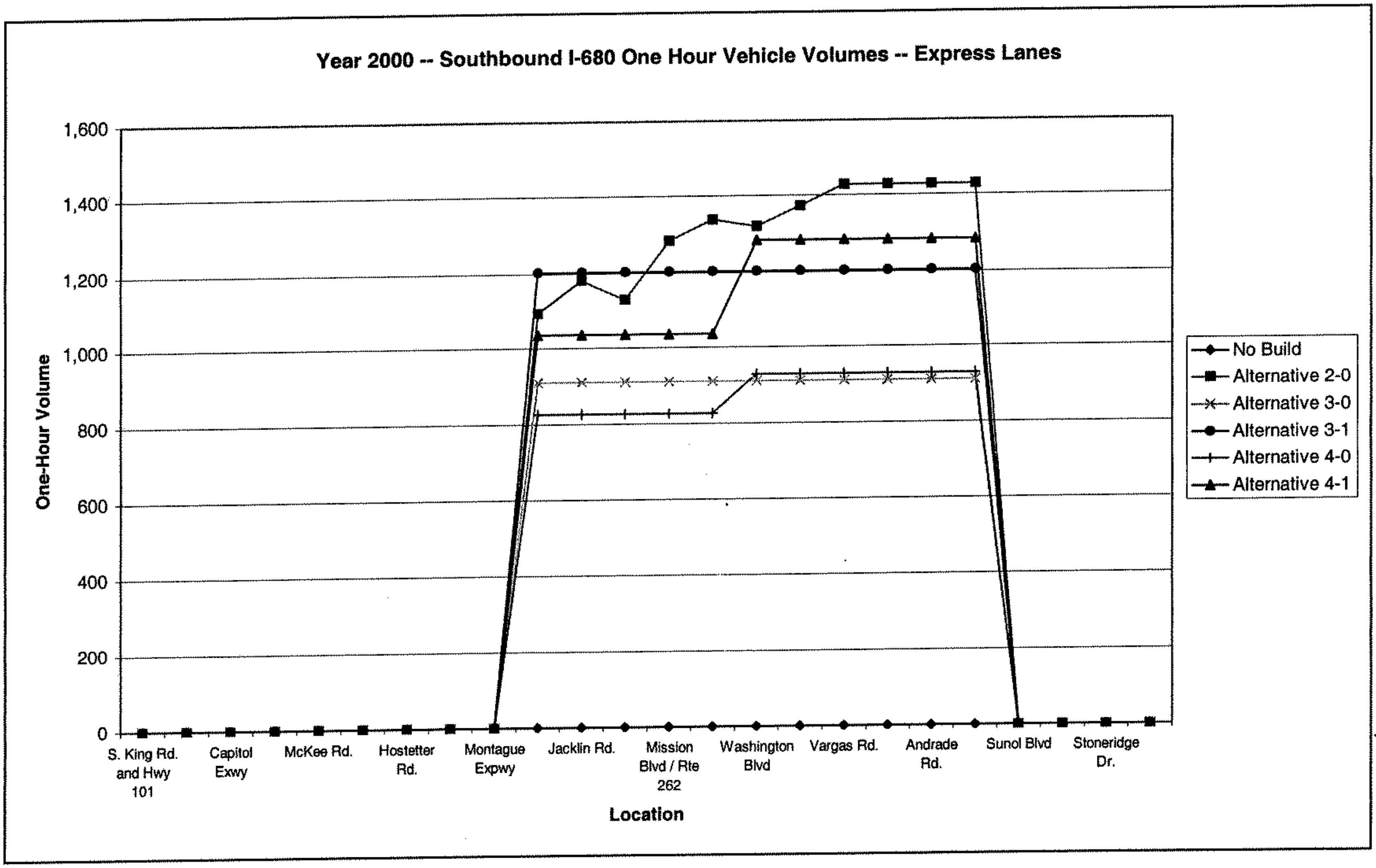

Figure 4-3: Year 2000 -- Southbound I-680 One Hour Vehicle Volumes -- Express Lanes

Figures 4-4 and 4-5 show how the volume/capacity ratios (a primary measure of congestion) of the general purpose and Express Lanes vary across alternatives.

In Figure 4-4, we first notice how the volume/capacity (v/c) ratios are greater than 1.00 across many segments of I-680. In reality, a roadway cannot move a volume of vehicles greater than its capacity – just as a gallon jug cannot hold more than a gallon of water. In conventional modeling, however, each vehicle seeks out a minimum path, and each trip which enters into the assignment, must be completed. And, although a heavy penalty is assessed to traveling on a congested roadway, many vehicles have no choice – each potential path is congested – and the result are roadways with a volume/capacity ratio greater than 1.00. It should also be noted that each individual roadway segment has an independent capacity. The capacities are adjusted to account for number of lanes, roadway width and curvature, and the surrounding area type.

Figure 4-4 demonstrates the same patterns shown in Figure 4-2 – the build alternatives have little impact on the general purpose lanes.

Figure 4-5 shows the v/c ratios for the Express Lanes. Again, the v/c ratios for the HOT alternatives (3 and 4) are directly dependent on the toll rate.

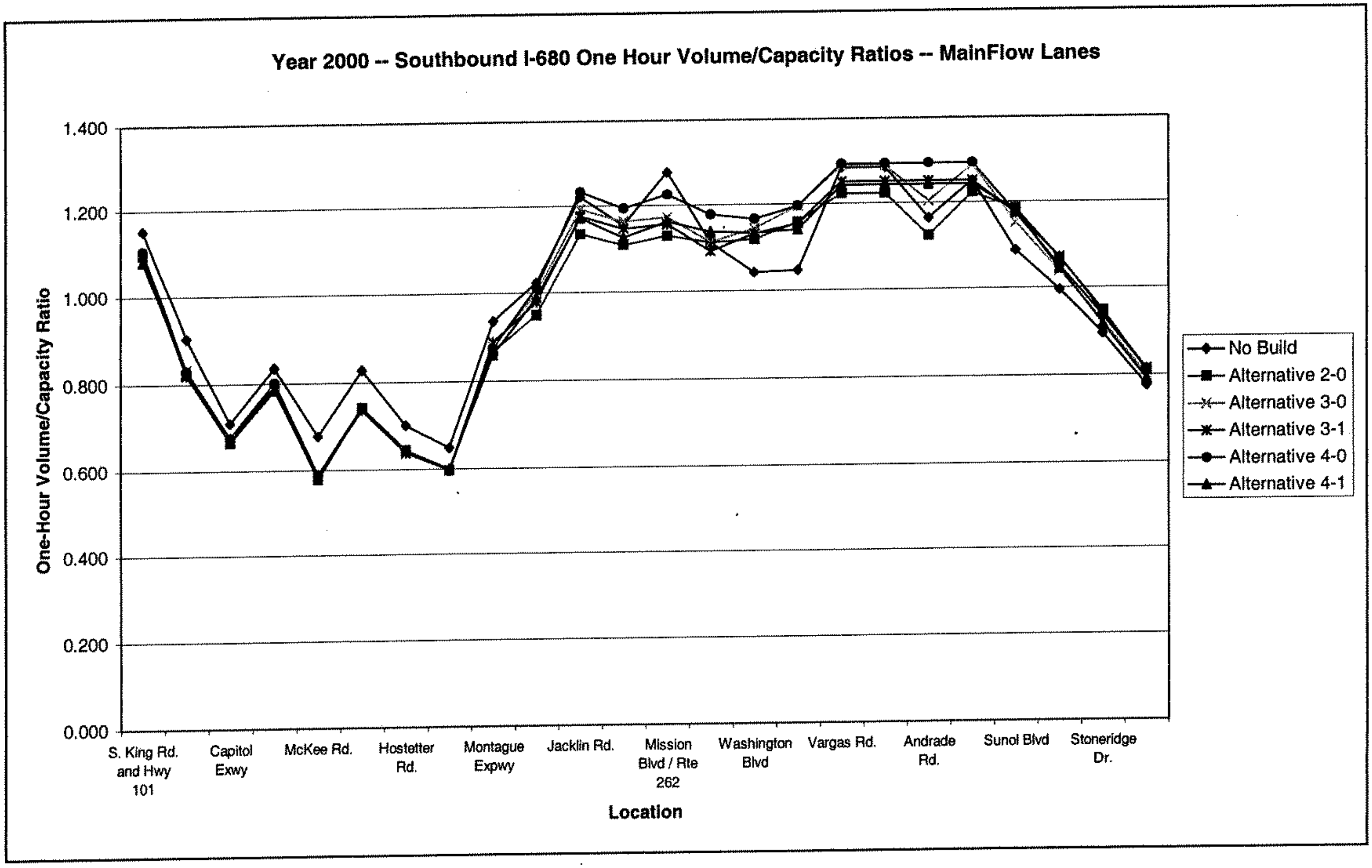

Figure 4-4: Year 2000 -- Southbound I-680 One Hour Volume/Capacity Ratios -- General Purpose Lanes

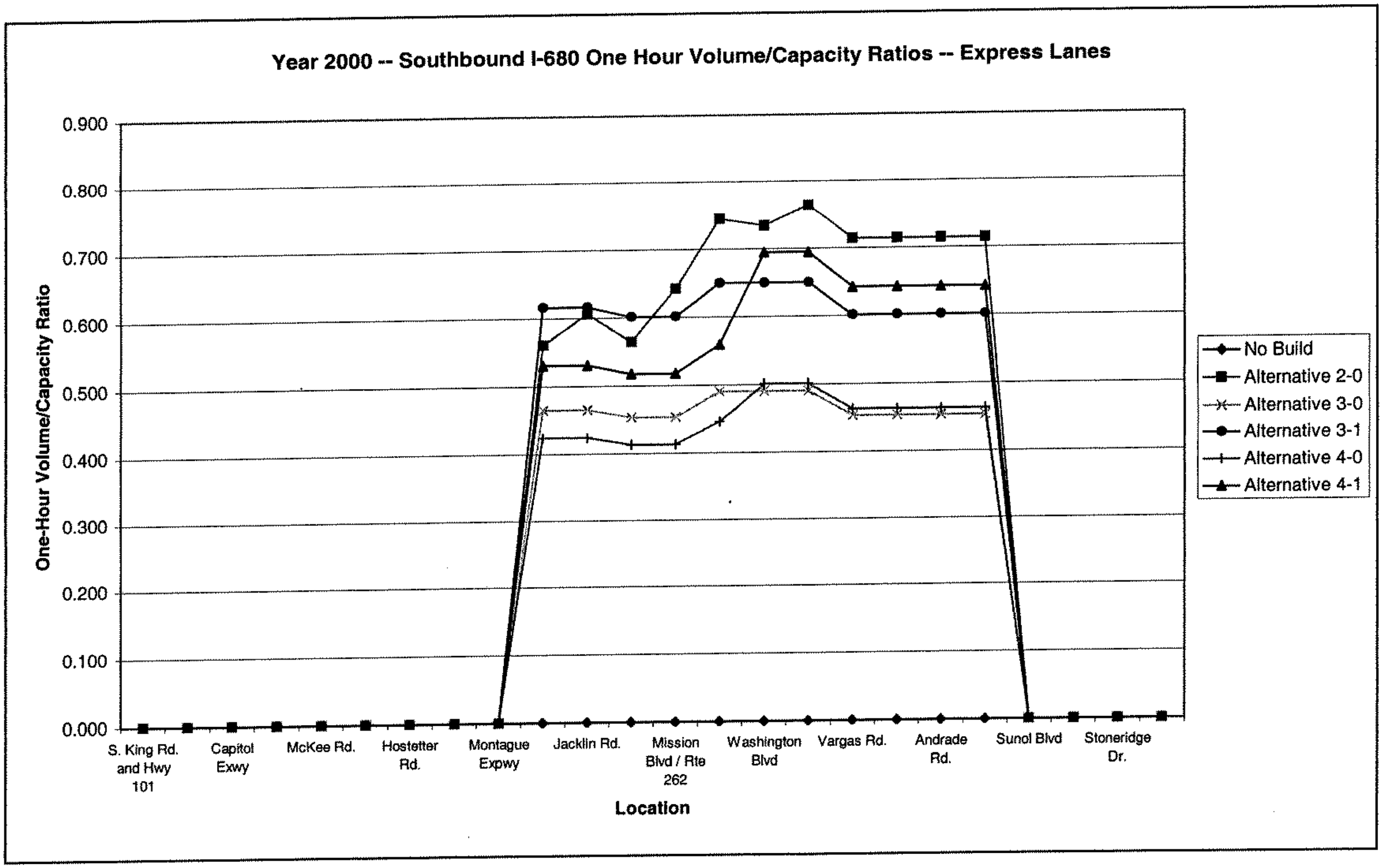

Figure 4-5: Year 2000 -- Southbound I-680 One Hour Volume/Capacity Ratios -- Express Lanes

Figures 4-6, 4-7, and 4-8 shift the emphasis from vehicular throughput to person throughput. In building HOV facilities, the goal is not to move more vehicles through the corridor, but rather to move more people through the corridor.

Figure 4-6 summarizes the person throughput for the entire facility – general purpose and Express lanes. The results indicate minor differences between the build alternatives with Alternative 2 moving the most people through the corridor.

Figure 4-7 demonstrates how the various Express lane types impact the person throughput of the general purpose lanes. Here, the No Build Alternative actually moves the most people on the general purpose lanes. Such a result is intuitive, in that the absence of an HOV lane would cause HOVs to use the general purpose lanes, which would increase the average vehicle occupancy.

Figure 4-8 summarizes the person throughput for the Express lanes and perhaps best illustrates the differences between the build alternatives. Alternative 2-0 generally moves the most people through the corridor. This is intuitive as an HOV facility forces travelers to join carpools to gain the travel time savings. When shifting to an HOT facility, access is limited, making the facility less useful to HOVs, some of whom will no longer use the facility.

Figure 4-8 also shows Alternatives 3-1 and 4-1 have slightly higher person throughput levels than Alternatives 3-0 and 4-0. This is a result of 2-person carpools forming much easier than 3+-person carpools. In Alternatives 3-1 and 4-1, the high number of HOVs increases the person throughput. In Alternatives 3-0 and 4-0, very few of the vehicles in the Express Lanes are HOVs, and as a result, the person throughput is much lower. The easy formation of 2-person carpools is a result of choice behavior captured in the mode choice models (i.e. it's easier to find one other person to share a ride with than two other people) as well as the 2025 highway system, which contains a rather complete network of HOV2+ facilities.

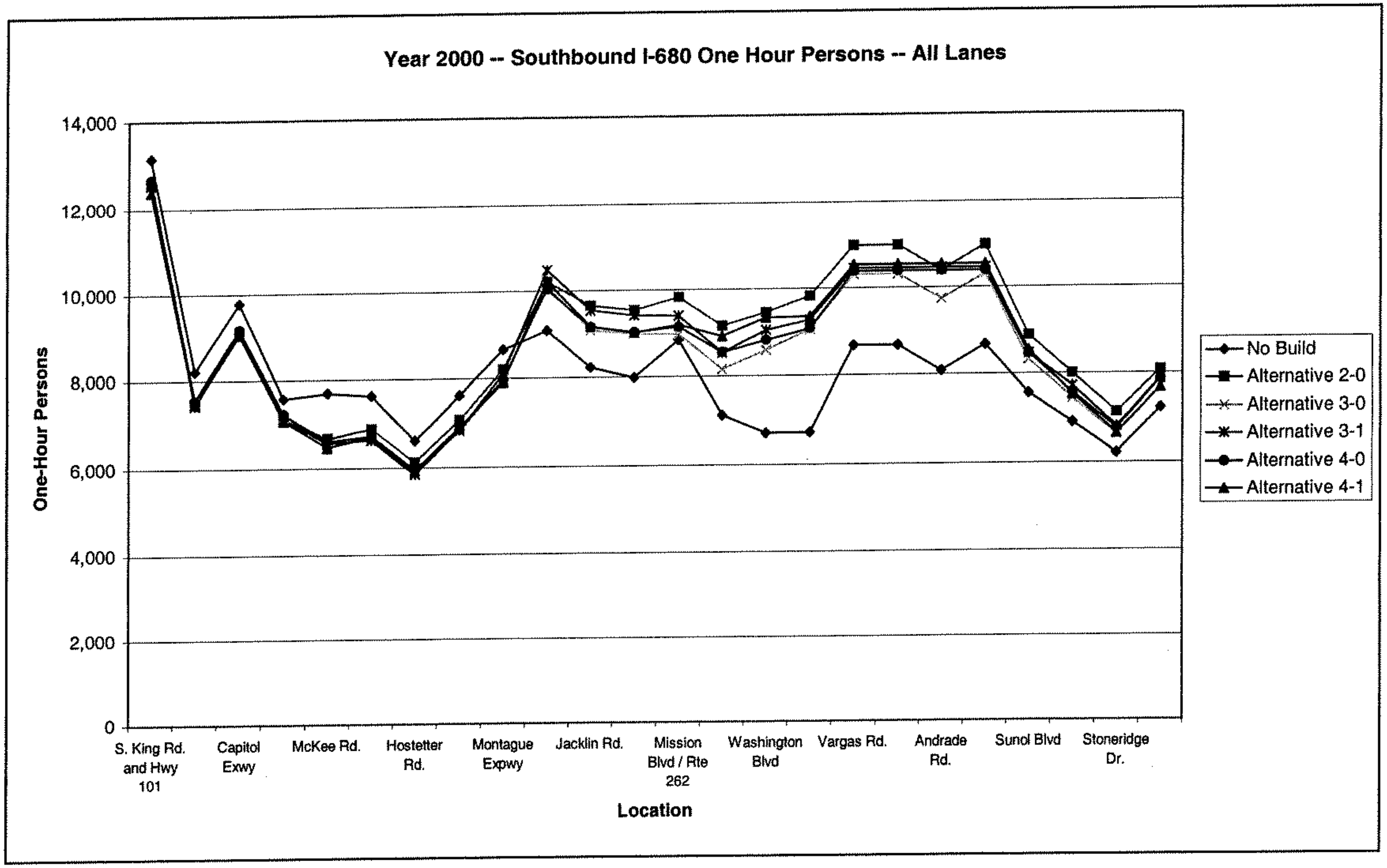

Figure 4-6: Year 2000 -- Southbound I-680 One Hour Persons -- All Lanes

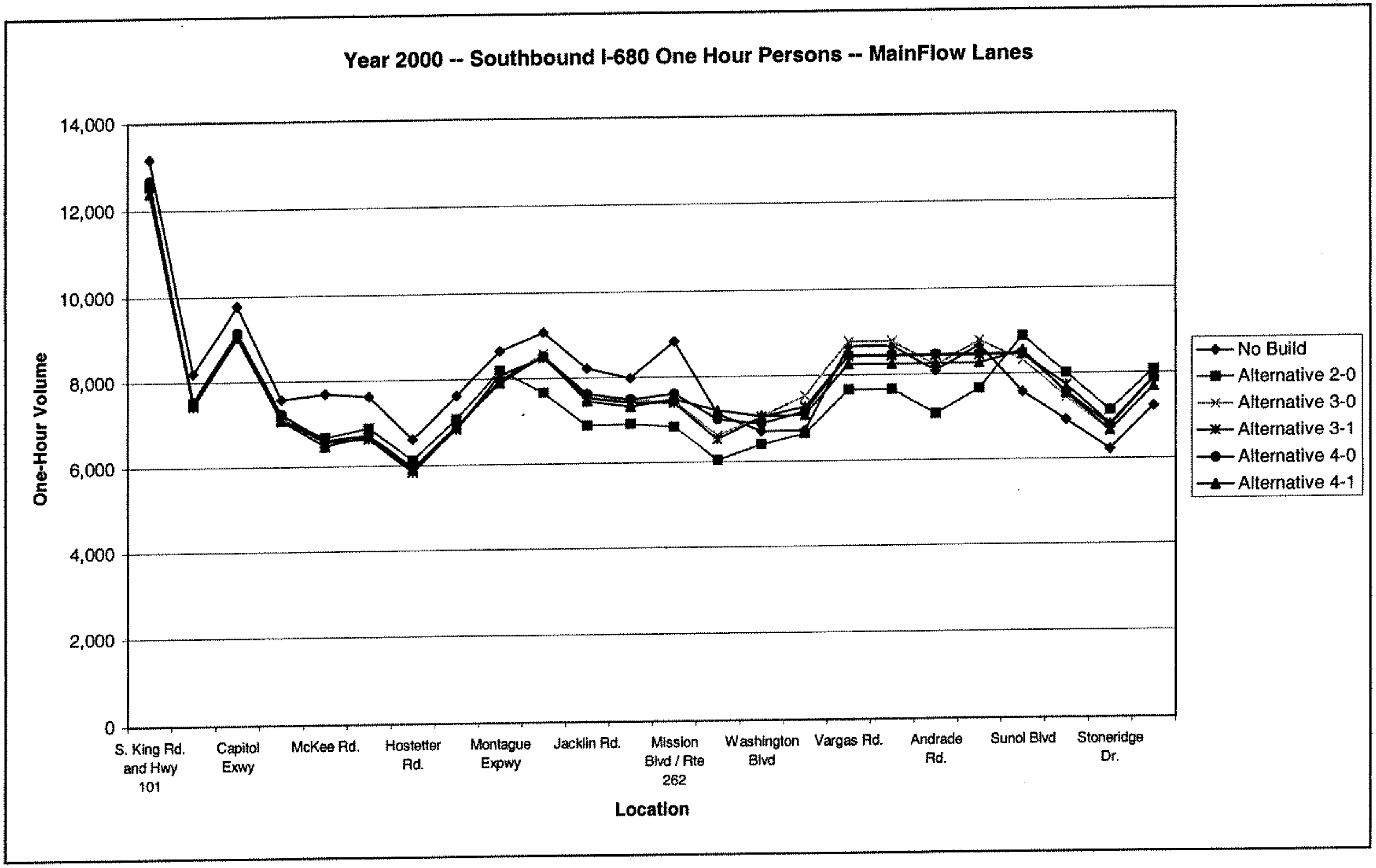

Figure 4-7: Year 2000 -- Southbound I-680 One Hour Persons -- General Purpose Lanes

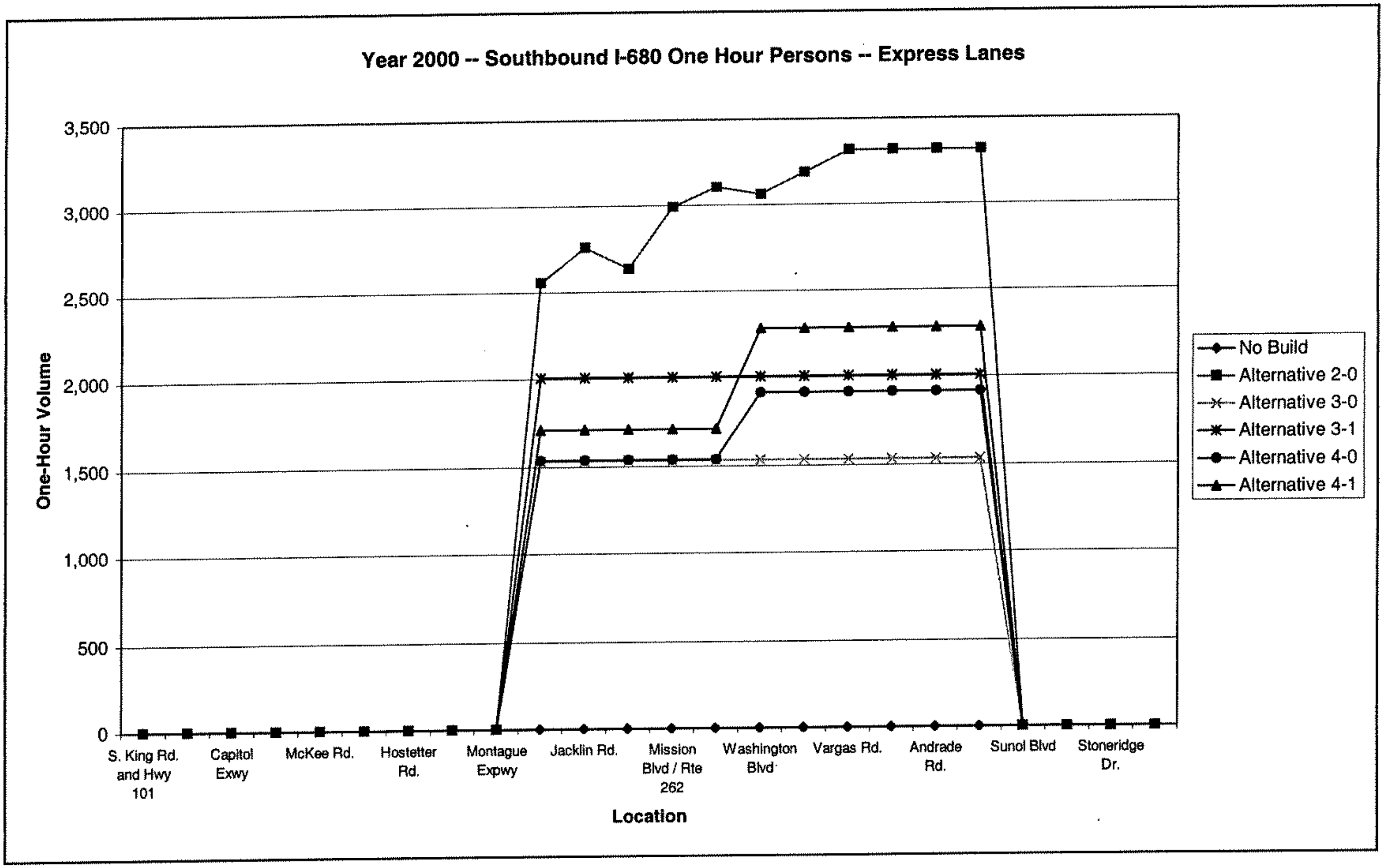

Figure 4-8: Year 2000 -- Southbound I-680 One Hour Persons -- Express Lanes

In addition to vehicle and person throughput, the travel time savings can offered by the Express Lanes can also be analyzed. Table 4-1 summarizes the travel time savings provided by the Express Lanes for each of the Alternatives. It should be noted that the time savings offered by the HOT alternatives (3 and 4) is a direct result of the toll charge and can be changed by modifying the toll rate.

Table 4-1 indicates the HOT alternatives can provide greater time savings than the HOV alternative (2-0).

Table 4-1: Year 2000 -- Travel Time Savings

Lane Type	Measure	Alternative 2 Secondary 0	Alternative 3 Secondary 0	Alternative 3 Secondary 1	Alternative 4 Secondary 0	Alternative 4 Secondary 1
Express	Travel Time Savings (minutes)	12.8	17.2	15.5	20.5	15.5
Mainflow	Travel Time (minutes)	28.5	32.2	30.9	35.4	30.9
	Travel Distance (miles)	15.2	15.2	15.2	15.2	15.2
	Average Speed (mph)	32.1	28.4	29.6	25.8	29.6
Express	Travel Time (minutes)	15.7	15.0	15.4	15.0	15.3
	Travel Distance (miles)	15.2	15.2	15.2	15.2	15.2
	Average Speed (mph)	58.3	61.0	59.5	60.9	59.5

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5. Year 2025 Model Results

This section presents the results in an identical format as Section 4: Year 2000 Model Results. The only difference between the 2000 Model runs and the 2025 Model runs are the input Socio-economic data and transit networks. The highway networks are identical.

Again, this section only presents the results for the Southbound AM Peak Hour. The toll optimization process was only done for the AM Period.

It should be noted, Alternative 1-0 and Alternative 2-0 are highly similar in the AM Period results. Alternative 1-0 contains a Southbound HOV lane but no Northbound HOV lane, which is present in Alternative 2-0. When looking at the AM Southbound results, Alternative 1-0 and 2-0 will look identical.

5.1 Year 2025, AM Period, Southbound (Commute) Direction Model Results

Figures 5-1, 5-2, and 5-3 present a summary of vehicle throughput across all alternatives for the AM Peak Hour assignment in the Southbound (commute) direction. The tabular data for these charts can be found in Appendix A: Tabular Data.

Figure 5-1 shows the total volumes moving through the I-680 corridor in both the general purpose and Express lanes. The vehicular throughput is nearly identical across the build alternatives. In comparison to Year 2000, we see the congestion is even more uniform as the already congested roadways become even more saturated.

Figure 5-2 demonstrates the alternative lane usage has essentially no impact on the general purpose lanes.

Figure 5-3 provides the vehicular volumes for the Express lanes. Again, it is important to note that the Express lane volume can be controlled by the Toll level charged to use the lane. In general, the same patterns in the Year 2000 results show up here. The HOV and HOT2+ scenarios (Alternatives 1, 2, 3-1, 4-1) contain higher volumes than the HOT3+ scenarios (Alternatives 3-0 and 4-0).

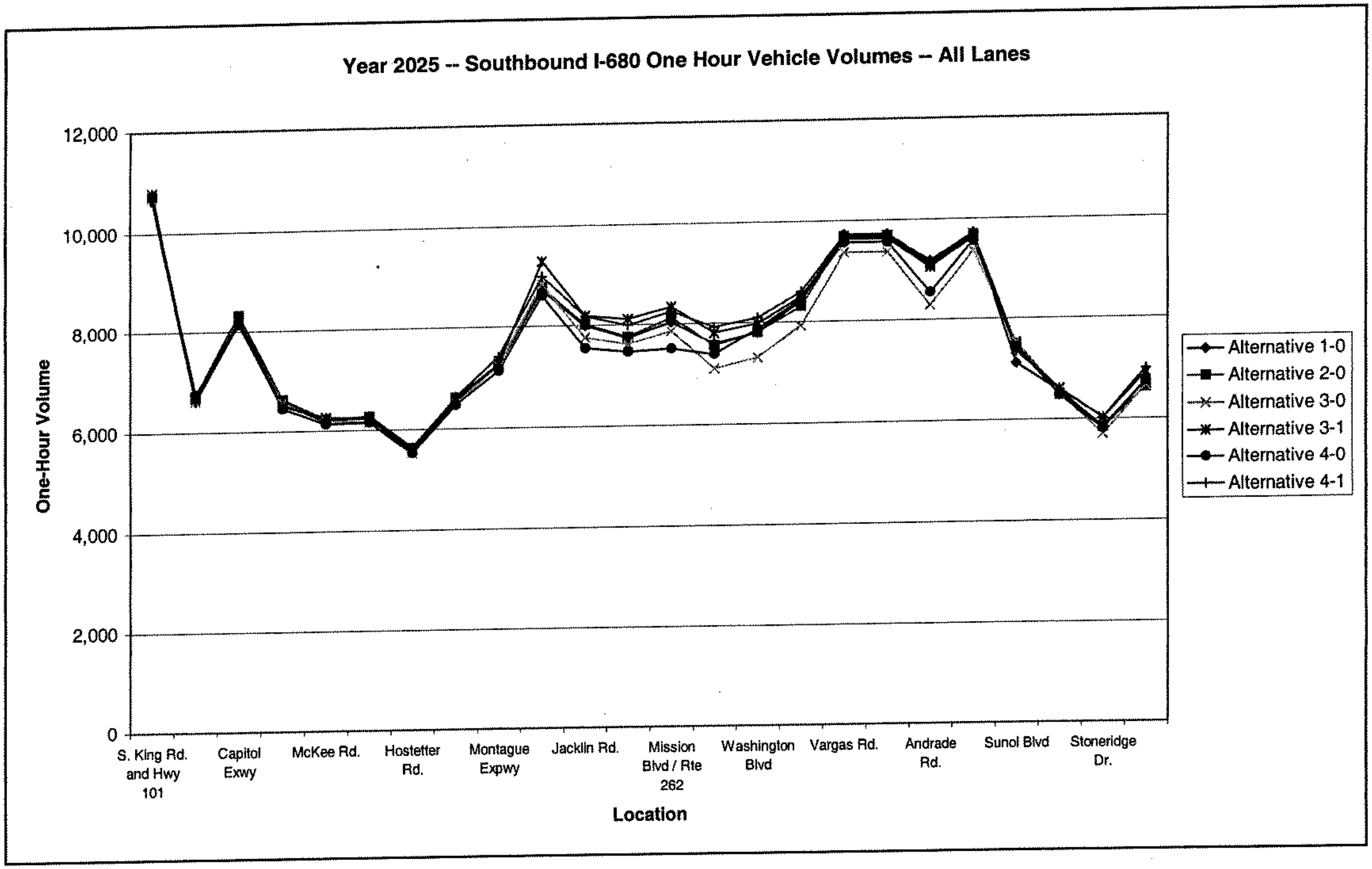

Figure 5-1: Year 2025 – Southbound I-680 One Hour Vehicle Volumes – All Lanes

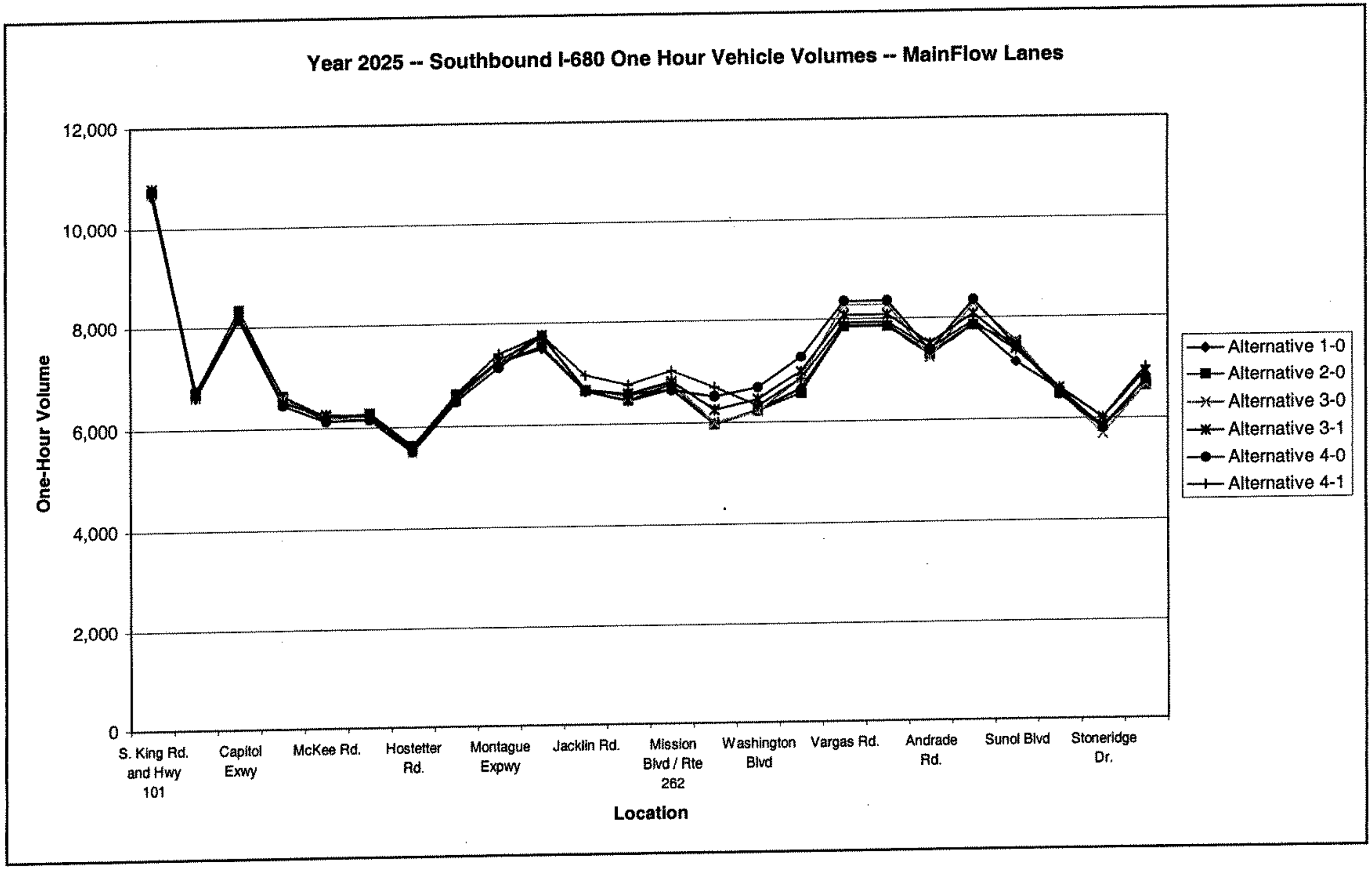

Figure 5-2: Year 2025 -- Southbound I-680 One Hour Vehicle Volumes -- General Purpose Lanes

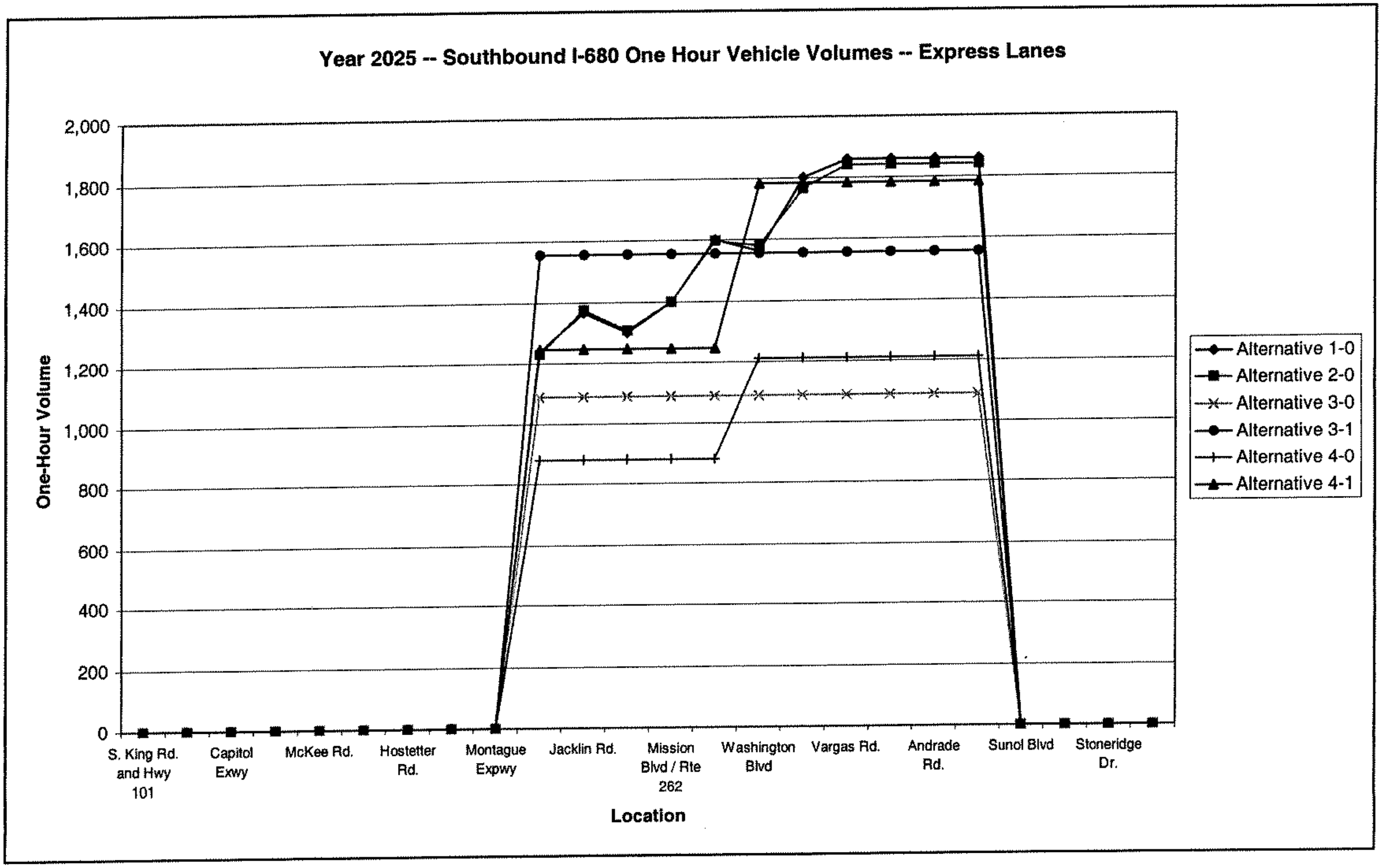

Figure 5-3: Year 2025 -- Southbound I-680 One Hour Vehicle Volumes -- Express Lanes

Figures 5-4 and 5-5 show how the volume/capacity ratios (a primary measure of congestion) of the general purpose and Express Lanes vary across alternatives.

In Figure 5-4, we again notice the v/c ratios are significantly greater than 1.00, indicating a high level of regional congestion. Also, the alternatives have a very minor impact on relieving the congestion on the general purpose lanes.

Figure 5-5 shows the v/c ratios for the Express Lanes. Again, the v/c ratios for the HOT alternatives (3 and 4) are directly dependent on the toll rate. The chart indicates the HOV lanes in Alternatives 1 and 2 are approaching capacity in Year 2025, as are the HOT2+ alternatives (3-1 and 4-1). The ability to avoid a congested Express Lane is a key benefit of the pricing strategy in Alternatives 3-0 and 4-0.

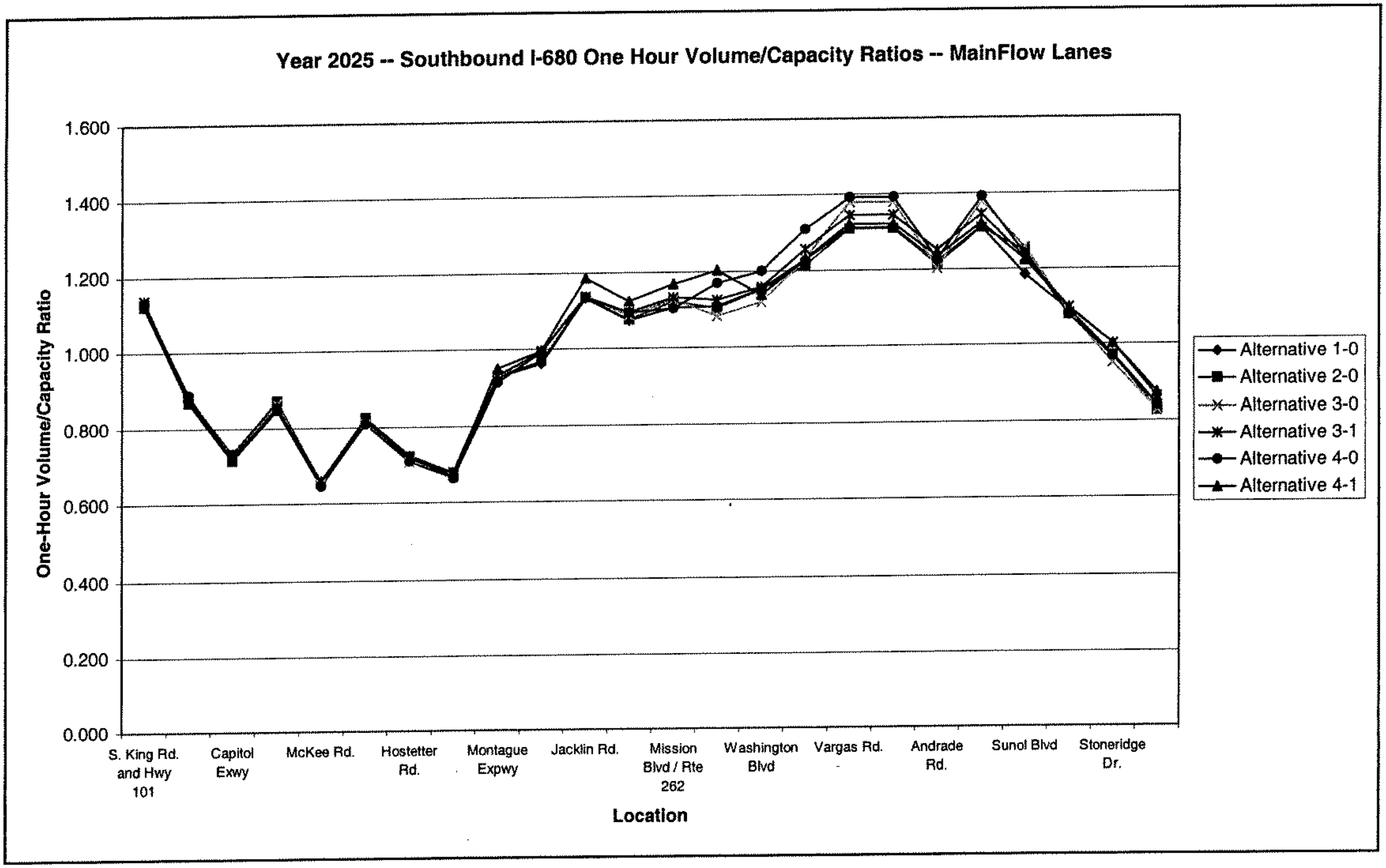

Figure 5-4: Year 2025 -- Southbound I-680 One Hour Volume/Capacity Ratios -- General Purpose Lanes

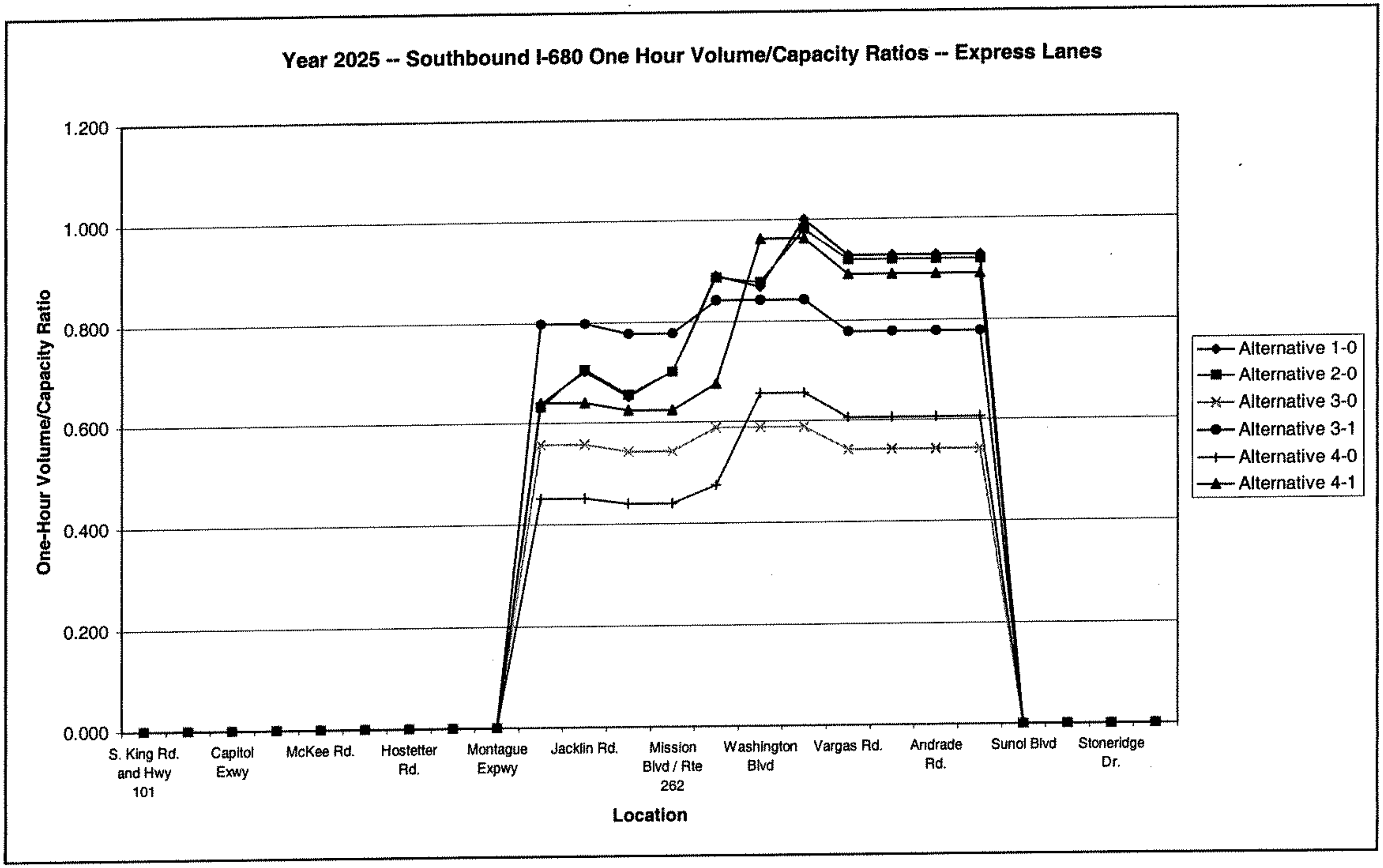

Figure 5-5: Year 2025 -- Southbound I-680 One Hour Volume/Capacity Ratios -- Express Lanes

Figures 5-6, 5-7, and 5-8 shift the emphasis from vehicular throughput to person throughput.

Figure 5-6 summarizes the person throughput for the entire facility – general purpose and Express lanes. The results indicate minor differences between the build alternatives with Alternatives 1 and 2 moving the most people through the corridor.

Figure 5-7 demonstrates how the various Express lane types impact the person throughput of the general purpose lanes. The results are identical to the Year 2000 condition, with the HOV alternatives (1 and 2) moving the fewest people through the general purpose lanes – an intuitive result.

Figure 5-8 summarizes the person throughput for the Express lanes and perhaps best illustrates the differences between the build alternatives. As in Year 2000, the HOV alternatives best move people through the Express Lanes.

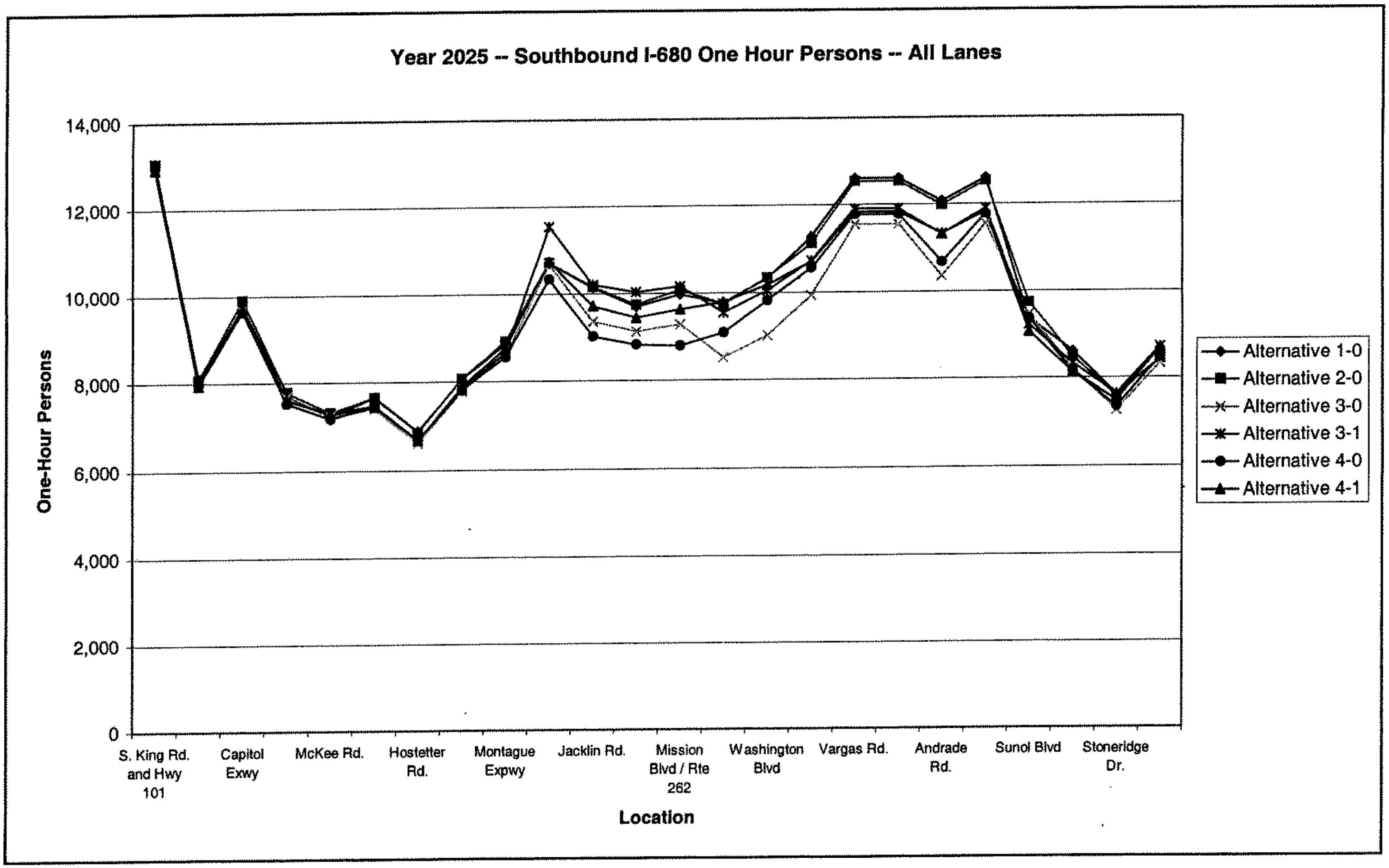

Figure 5-6: Year 2025 -- Southbound I-680 One Hour Persons -- All Lanes

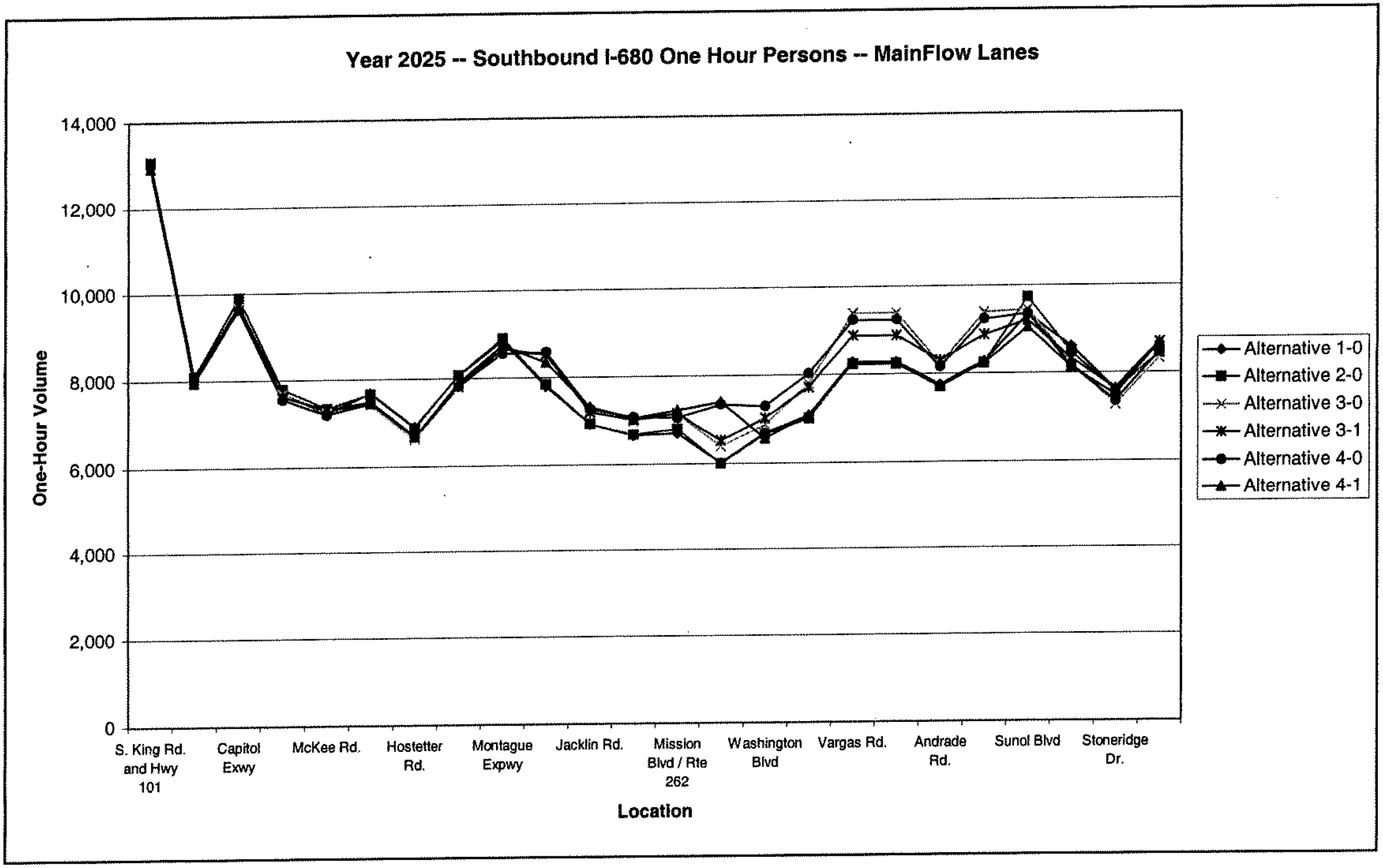

Figure 5-7: Year 2025 -- Southbound I-680 One Hour Persons -- General Purpose Lanes

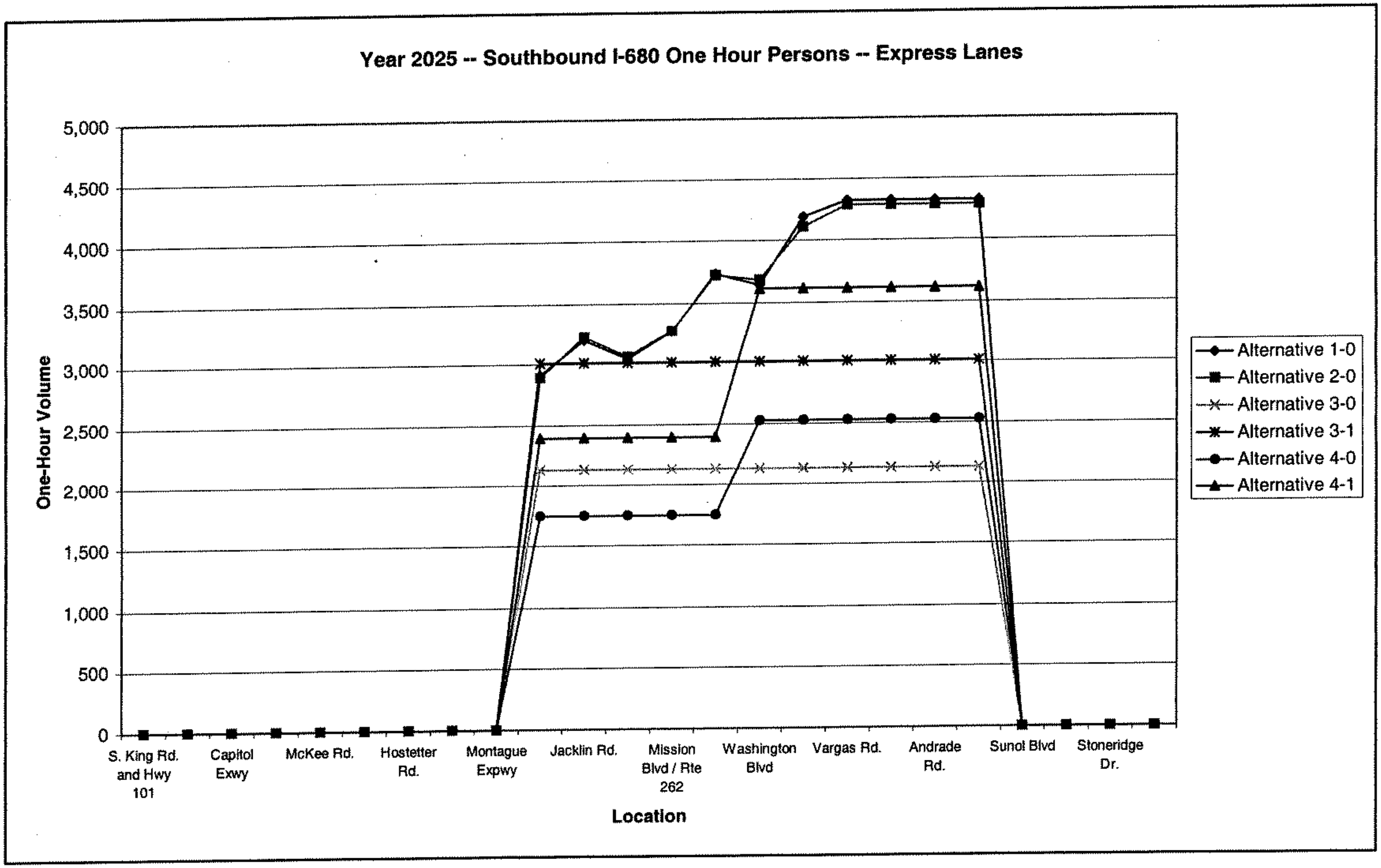

Figure 5-8: Year 2025 -- Southbound I-680 One Hour Persons -- Express Lanes

Table 5-1 summarizes the travel time savings offered by each of the Build Alternatives for Year 2025. Because of the extreme congestion in the general pupose lanes, small differences in the general purpose volumes can have a large impact on the travel time. For example, the general purpose volumes for Alternatives 2 and 3-0 are nearly identical (see Figure 5-2), but their travel times differ by 5 minutes. This condition muddles the travel time savings results a bit, but the general pattern of the Express Lane offering approximately 20 minutes of time savings holds for each of the Alternatives.

Table 5-1: Year 2025 -- Travel Time Savings

Lane Type	Measure	Alternative 1 Secondary 0	Alternative 2 Secondary 0	Alternative 3 Secondary 0	Alternative 3 Secondary 1	Alternative 4 Secondary 0	Alternativ 4 Secondar 1
Express	Travel Time Savings (minutes)	20.0	21.6	17.9	16.7	20.7	16.[illegible]
Mainflow	Travel Time (minutes)	38.8	39.7	33.1	33.6	35.9	33.[illegible]
	Travel Distance (miles)	15.2	15.2	15.2	15.2	15.2	15.[illegible]
	Average Speed (mph)	23.5	23.0	27.6	27.2	25.5	27.[illegible]
Express	Travel Time (minutes)	18.9	18.2	15.2	16.9	15.2	17.[illegible]
	Travel Distance (miles)	15.2	15.2	15.2	15.2	15.2	15.[illegible]
	Average Speed (mph)	48.4	50.3	60.2	54.1	60.2	52.[illegible]

6. Conclusions

The travel demand portion of the I-680 Value Pricing Study allowed for a rational comparison of High Occupancy Vehicle (HOV) and High Occupancy Toll (HOT) strategies for operating and Express Lane in the I-680 Freeway between the Sunol Grade and San Jose.

Appendix A: Tabular Data

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